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Remediation Technologies for Environmental Projects in the United States Military: Part II

by

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19980727 033

Thesis

Presented to the Faculty of the Graduate School

of the University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Engineering

The University of Texas at Austin

May 1998

Remediation Technologies for Environmental Projects

in the United States Military: Part II

APPROVED BY

SUPERVISING COMMITTEE:

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ABSTRACT

Remediation Technologies for Environmental Projects in the United States Military: Part II

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The University of Texas at Austin, 1998

SUPERVISOR: James T. O'Connor

This thesis analyzes the performance of environmental restoration and compliance projects in the Department of Defense. The thesis is the second part of a two-part study examining project cost, schedule, and technical performance. The soundness of the reasons for a specific remediation technology selection are explored and tested. The research consists of data collection, statistical analysis, and formulating conclusions and recommendations. This thesis demonstrates that planning environmental restoration and compliance projects using formalized decision matrices can increase the likelihood of project success.

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Chapter 1. Introduction

1.1 Background and Motive

This thesis analyzes the performance of environmental restoration and compliance projects in the Department of Defense. The thesis is the second part of a two-part study examining project cost, schedule, and technical performance on such projects. The soundness of the reasons for a specific remediation technology selection are explored and tested. The research consists of data collection, statistical analysis, and the formulation of conclusions and recommendations. This thesis demonstrates that planning environmental restoration and compliance projects using formalized decision matrices can increase the likelihood of project success.

1.2 Purpose of this Research

The primary objective of this research was to formulate a better understanding of the management of environmental restoration and compliance projects. This study provides analysis of environmental remediation technologies, their performance from a project manager's perspective, and the effectiveness of the reasons for their selection.

1.3 Research Scope

This research is part of a two-part study of project management on environmental remediation projects in the Department of Defense (DOD). Part I included the following activities:

- Research project definition
- Literature review
- Preparation of data collection instrument
- Data collection from U.S. Air Force sources
- Design and development of relational database
- Recommendations for analysis

This thesis is Part II of the study and includes:

- Data collection from U.S. Navy sources
- Application of the relational database
- Data analysis and presentation of conclusions and recommendations

1.4 Research Hypotheses

Eight hypotheses have been tested in this research. They include the following:

1. That project cost performance *does vary* with technology implemented.
2. That project schedule performance *does vary* with technology implemented.
3. That project scope performance *does vary* with technology implemented.
4. That project scope performance *does vary* with reason for technology selection.
5. That project cost performance *does not vary* with contaminant type.
6. That project schedule performance *does not vary* with contaminant type.
7. That project schedule performance *does not vary* with reason for technology selection.

8. That project cost performance *does not vary* with reason for technology selection.

1.5 Structure of this Thesis

Following this introductory chapter, Chapter Two is dedicated to summarizing Part I of the study, the work of Captain Scot T. Allen, USAF. Chapter Three is a detailed explanation of the research methodology. Next, a graphical presentation of the data and statistical data analysis is performed in Chapter Four. Chapter Five presents final conclusions and recommendations.

Chapter 2. Summary of Remediation Technologies for Environmental Projects in the United States Military: Part I

This thesis is the second part of a two-part study. This chapter is dedicated to summarizing Part I, the work of Captain Scot T. Allen, USAF. A complete copy of his Thesis is on record at The University of Texas at Austin.

2.1 Background

> Since the enactment of the Comprehensive Environmental Response Compensation, and Liability Act (CERCLA) in 1980, when Congress established a $1.6 billion "Superfund" for environmental remediation of past contaminated sites, it has been recognized that the costs of cleaning up polluted areas will be several orders of magnitude higher than previous estimates (LaGrega 1994). Annual spending on environmental protection and restoration in the U.S. is expected to reach $185 billion by the year 2000 (Kenkeiemath 1996).... Cost projections for site remediation alone exceed $1 trillion distributed over the next two decades (Blackburn 1993). (Allen 1997)

The U.S. armed forces have closed the era in American history of inattention to environmental issues and are aggressively pursuing clean up projects at Department of Defense (DOD) installations. The Department of the Navy (DON) has identified 4433 sites that require environmental investigation and possible remediation: 1382 of the sites have been remediated, 2549 sites are in the study phase, and 502 had a cleanup underway as of 30 September 1996 (DON 1996). The cost of environmental remediation is high. The Navy's Fiscal Year 1998 budget includes $675 million for environmental studies, cleanup, restoration, and compliance. Base realignment and closure is associated with $361 million of that figure (USA 1998).

2.2 Management of Environmental Remediation Projects

Two aspects of environmental remediation project management that differ from conventional construction management are the technology selection decision and the way that risk is managed in the project. In the construction industry, risk is assigned through legal contracts between owners and contractors. The most common type of construction contract, lump sum (also called firm, fixed price) assigns almost all of the risk to the contractor. The cost reimbursable contract type assigns the majority of project risk to the owner. The end result of a construction contract is a tangible facility while the site of a remediation project may not look significantly different to the casual observer even after millions of dollars have been spent. The scope of an environmental remediation project may be very hard to distinctly quantify. This increased uncertainty in environmental projects makes the contract type selection more difficult. According to the Construction Industry Institute (CII), "The unusual features of contaminated site remediation projects suggest that non-traditional or innovative management and contracting strategies may be beneficial." CII research indicates that contracts, which share risk, yield better results with less cost overruns (CII 1995). (Allen 1997)

2.3 Site Remediation Technology

Captain Allen profiled the main remediation technologies currently used by the U.S. military. He discussed the pros and cons of *in situ* (in place) and *ex situ* (excavation / pumping) solutions and gave a good description of the techniques, constraints, favorable conditions, and cost estimate ranges for the following technologies:

Soil vapor extraction	Low permiability soil cap
Air sparging	Passive treatment wall
Biodegradation	Groundwater pump and treat
Bioventing	Excavation and land disposal
Chemical reduction / oxidation	Excavation and incineration
Composting	And several innovative technologies

Many remediation technologies have been developed to treat contaminated soil and groundwater. The Environmental Protection Agency (EPA) has supported research on these technologies through the Superfund Innovative Technology Evaluation (SITE) program and the Technical Support Project (Scalf 1992). Information on nearly 350 technologies is now available through the EPA's Hazardous Waste Clean Up Information Web site on the Vendor Information Systems for Innovative Treatment Technologies (VISITT) database. This database can be downloaded for no charge from within the "Supply and Demand" section of EPA's web site, http://clu-in.com (EPA 1997). (Allen 1997)

2.4 Remediation Technology Selection

Captain Allen discussed three decision matrixes currently used by the Air Force to determine the optimum technology to address the particular conditions at the site. Only the two that are used in future analysis will be commented on here.

DOD Treatment Technologies Screening Matrix

The Remediation Technologies Screening Matrix and Reference Guide provides a screening matrix for 55 different remediation technologies (see Table 2.1). These technologies have been evaluated based on the following factors: their development status and commercial availability, the residuals generated, the contaminants treated, reliability and maintainability, schedule, and cost. This guide is particularly helpful to the project manager faced with an unusual site or who wants to find an appropriate innovative technology (DOD 1994). (Allen 1997)

Air Force Center for Environmental Excellence Remediation Matrix

The Air Force Center for Environmental Excellence (AFCEE) has developed a decision-making tool entitled the Remediation Matrix-Hierarchy of Preferred Alternatives (see Table 2.2). This matrix provides a rank ordering of remediation alternatives for a given contaminant and zone of contamination (i.e. dissolved fuel in groundwater). This remediation matrix also provides a prioritized list of technologies to consider during project planning. Under a peer review system now in place in the Air Force, remediation managers who elect not to use AFCEE's recommended solution for a particular contamination scenario must specifically justify the use of another technology (Allen 1997).

The next section discusses the method of study for this research. The sequence of analysis, statistical analysis, and methods of handling data are presented in detail.

NOTE: Specific site and contaminant characteristics may limit the applicability and effectiveness of any of the technologies and treatments listed below. This matrix is optimistic in nature and should always be used in conjunction with the *referenced text sections,* which contain additional information that can be useful in identifying potentially applicable technologies.

SOIL, SEDIMENT, AND SLUDGE	Development Status	Availability	Residuals Produced	Treatment Train (excludes off-gas treatment)	Contaminants Treated: VOCs	SVOCs	Fuels	Inorganic	Explosives	System Reliability/ Maintainability	Cleanup Time	Overall Cost	O&M or Capital Intensive
3.1 In Situ Biological Treatment													
4.1 Biodegradation	Full	■	None	No	■	■	■	△	■	△	△	●	O&M
4.2 Bioventing	Full	■	None	No	■	■	■	△	I	■	●	■	Neither
4.3 White Rot Fungus	Pilot	△	None	No	△	△	△	△	■	△	△	●	O&M
3.2 In Situ Physical/Chemical Treatment													
4.4 Pneumatic Fracturing (enhancement)	Pilot	△	None	Yes	●	●	●	●	●	■	NA	■	Neither
4.5 Soil Flushing	Pilot	■	Liquid	No	■	●	●	■	△	●	△	I	O&M
4.6 Soil Vapor Extraction (In Situ)	Full	■	Liquid	No	■	●	■	△	△	■	●	■	O&M
4.7 Solidification/Stabilization	Full	■	Solid	No	△	●	△	■	△	■	■	■	CAP
3.3 In Situ Thermal Treatment													
4.8 Thermally Enhanced SVE	Full	●	Liquid	No	●	■	●	△	△	●	■	●	Both
4.9 Vitrification	Pilot	△	Liquid	No	●	●	●	■	△	△	■	△	Both
3.4 Ex Situ Biological Treatment (assuming excavation)													
4.10 Composting	Full	■	None	No	■	●	■	△	■	■	●	■	Neither
4.11 Controlled Solid Phase Bio. Treatment	Full	■	None	No	■	●	■	△	■	■	●	■	Neither
4.12 Landfarming	Full	■	None	No	■	●	■	△	●	■	△	■	Neither
4.13 Slurry Phase Bio. Treatment	Full	●	None	No	■	●	■	△	■	●	●	●	Both
3.5 Ex Situ Physical/Chemical Treatment (assuming excavation)													
4.14 Chemical Reduction/Oxidation	Full	■	Solid	Yes	●	●	●	■	△	■	■	●	Neither
4.15 Dehalogenation (BCD)	Full	△	Vapor	No	●	■	△	△	△	I	I	I	I
4.16 Dehalogenation (Glycolate)	Full	●	Liquid	No	●	■	△	△	△	△	△	△	Both
4.17 Soil Washing	Full	●	Solid, Liquid	Yes	●	■	■	■	■	●	■	●	Both
4.18 Soil Vapor Extraction (Ex Situ)	Full	■	Liquid	No	■	●	●	△	△	■	●	■	Neither
4.19 Solidification/Stabilization	Full	■	Solid	No	△	●	△	■	△	■	■	■	CAP
4.20 Solvent Extraction (chemical extraction)	Full	●	Liquid	Yes	●	■	●	△	■	●	△	△	Both
3.6 Ex Situ Thermal Treatment (assuming excavation)													
4.21 High Temperature Thermal Desorption	Full	■	Liquid	Yes	●	■	●	△	△	●	■	●	Both
4.22 Hot Gas Decontamination	Pilot	●	None	No	△	△	△	△	■	■	■	■	Both
4.23 Incineration	Full	■	Liquid,Solid	No	●	■	■	△	■	●	■	△	Both
4.24 Low Temperature Thermal Desorption	Full	■	Liquid	Yes	■	●	■	△	■	●	■	■	Both
4.25 Open Burn/Open Detonation	Full	■	Solid	No	△	△	△	△	■	■	■	■	Both
4.26 Pyrolysis	Full	△	Liquid,Solid	No	●	■	●	△	I	I	■	△	Both
4.27 Vitrification	Full	●	Liquid	No	●	●	●	■	△	●	●	△	Both
3.7 Other Treatment													
4.28 Excavation, Retrieval, and Off-Site Disposal	NA	■	NA	No	●	●	●	●	●	■	■	△	Neither
4.29 Natural Attenuation	NA	■	None	No	■	■	■	△	△	■	△	■	Neither

Table 2.1 DOD Technology Screening Matrix (DOD 1994)

GROUNDWATER, SURFACE WATER, AND LEACHATE													
3.8 In Situ Biological Treatment													
4.30	Co-metabolic Treatment	Pilot	△	None	No	■	■	●	△	●	△	●	●	O&M
4.31	Nitrate Enhancement	Pilot	△	None	No	■	■	■	△	●	●	●	■	Neither
4.32	Oxygen Enhancement with Air Sparging	Full	■	None	No	■	■	■	△	●	■	●	■	Neither
4.33	Oxygen Enhancement with H_2O_2	Full	■	None	No	■	■	■	△	●	△	●	●	O&M
3.9 In Situ Physical/Chemical Treatment														
4.34	Air Sparging	Full	■	Vapor	Yes	■	△	■	△	△	■	■	■	Neither
4.35	Directional Wells (enhancement)	Full	△	NA	Yes	●	●	●	●	●	●	■	I	Neither
4.36	Dual Phase Extraction	Full	■	Liquid,Vapor	Yes	■	△	■	△	△	●	●	●	O&M
4.37	Free Product Recovery	Full	■	Liquid	No	△	■	■	△	△	●	■	■	Neither
4.38	Hot Water or Steam Flushing/Stripping	Pilot	●	Liquid,Vapor	Yes	●	■	■	△	△	△	■	●	CAP
4.39	Hydrofracturing (enhancement)	Pilot	I	None	Yes	●	●	●	●	●	■	■	●	Neither
4.40	Passive Treatment Walls	Pilot	△	Solid	No	■	■	●	■	■	I	△	I	CAP
4.41	Slurry Walls (containment only)	Full	■	NA	NA	●	●	●	●	●	■	■	■	CAP
4.42	Vacuum Vapor Extraction	Pilot	△	Liquid,Vapor	No	■	●	■	I	△	■	●	●	CAP
3.10 Ex Situ Biological Treatment (assuming pumping)														
4.43	Bioreactors	Full	■	Solid	No	■	■	■	△	●	●	NA	■	CAP
3.11 Ex Situ Physical/Chemical Treatment (assuming pumping)														
4.44	Air Stripping	Full	■	Liquid,Vapor	No	■	●	●	△	△	■	NA	■	O&M
4.45	Filtration	Full	■	Solid	Yes	△	△	△	■	●	■	■	■	Neither
4.46	Ion Exchange	Full	■	Solid	Yes	△	△	△	■	△	■	●	■	Neither
4.47	Liquid Phase Carbon Adsorption	Full	■	Solid	No	■	■	●	●	■	■	NA	△	O&M
4.48	Precipitation	Full	■	Solid	Yes	△	△	△	■	I	■	●	■	Neither
4.49	UV Oxidation	Full	■	None	No	■	■	■	△	■	△	NA	●	Both
3.12 Other Treatment														
4.50	Natural Attenuation	NA	■	None	No	■	■	■	△	△	■	△	■	Neither
3.13 AIR EMISSIONS/OFF-GAS TREATMENT														
4.51	Biofiltration	Full	●	None	NA	■	●	■	△	●	△	NA	●	Neither
4.52	High Energy Corona	Pilot	△	None		■	■	■	●	△	△	NA	●	I
4.53	Membrane Separation	Pilot	△	None		■	●	●	△	●	△	NA	●	I
4.54	Oxidation	Full	■	None		■	■	■	△	●	■	NA	■	Neither
4.55	Vapor Phase Carbon Adsorption	Full	■	Solid		■	■	■	●	■	■	NA	■	Neither

Rating Codes (See Table 3-1)

■ Better
● Average
△ Worse
I Inadequate Information
NA Not Applicable

Table 2.1 DOD Technology Screening Matrix (Continued) (DOD 1994)

	POL-Vadose Zone (ie. Jet fuel, diesel)	Chlorinated Solvent Vapor Treatment	Dissolved Fuel in Ground Water (BTEX)	Chlorinated Solvents in Vadose Zone (ie. TCE)	Dissolved Chlorinated Solvents in Ground Water	Heavy Metals in Vadose Zone	Heavy Metals in Excavated Soil	POL Vapor Treatment	POL-Excavated Soil
Natural Attenuation/Assimilation	1		1	1	1	1	1		1
Bioventing	2			3					4
Soil Vapor Extraction	3			2					5
Heat Enhanced Vapor Extraction	4			4					
Low Permeability Cover/Cap	5			6		3			
Excavate and/or Haul	6			7		4	4		8
Composting (no tilling)									2
Land Farming							2		3
Low Temp Thermal Desorp									6
Incineration (high temp)									7
Air Sparging			3		3				
Passive Treatment Wall			4		4				
Conventional Pump and Treat			5		5				
Slurry Wall			6		6				
Stabilization				5		2	3		
Permitted Direct Emission		1						1	
Flare								2	
Biological Filter		4						6	
Catalytic Incineration		2						4	
On-site Regenerative Polymer		3						5	
Carbon Adsorption								7	
Internal Combustion Engine								3	
GW Recirculation/Stripping		5	2		2				

This Matrix is an attemp to rank technologies/processes that should be considered for use at common Air Force sites. Managers should use this hierarchy for screening technologies/processes and should be able to justify why a particular technology/process was selected over others with lower numbers. Certain categories of the original Matrix were not used in this study and are not shown to enhance the clarity of the table.

Table 2.2 AFCEE Remediation Matrix - Modified (AFCEE 1994)

Chapter 3 Study Methodology

The research procedure of the study is shown in Figure 3.1. Part I of this study was completed by Captain Scot T. Allen, 26 August 1997, and included project definition, literature review, data collection tool preparation, database

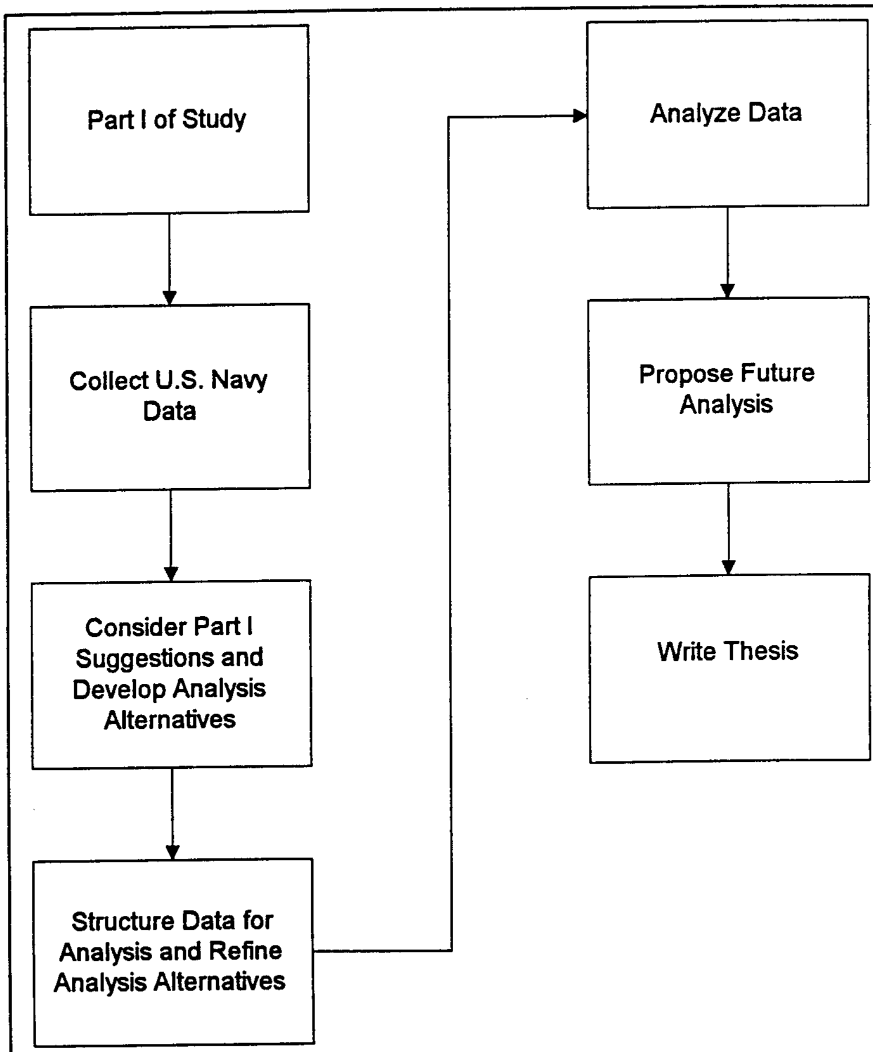


Figure 3.1: Research Plan for Part II

development and collection of U.S. Air Force data. His research plan for Part I is included in Appendix A. This thesis included additional data gathering from U.S. Navy sources and analysis. As mentioned in Part I, "Future refinement of this research could include the collection of data from the U.S. Army, other government agencies, or the private sector." (Allen 1997). In this chapter, data collection and analysis will be explained. Recommendations for future analysis will be addressed but specific issues and additional data collection will be fully addressed in Chapter 5.

3.1 Development of Data Gathering Tool - Project Survey

Captain Allen developed a data gathering tool, a "Project Survey", with input from professors in the faculty of Construction Engineering and Project Management, Environmental and Water Resources Engineering, and Geotechnical Engineering programs. His goals and objectives were to: 1) have a short survey so that respondents would not be dismayed at the task, and 2) to cover contamination type, geotechnical conditions, technology selected, reason technology was selected, contract type, duration and cost. Project managers were also asked to evaluate their projects considering cost and schedule performance and numerous subjective items. The target time to complete a survey was ten to fifteen minutes and feedback illustrated that this goal was met. This survey in included as Appendix B.

U.S. Navy data collection for Part II began in August 1997. After personally contacting project managers or their supervisors by telephone, approximately sixty-nine data collection surveys were distributed to twenty-three project managers by mail, e-mail, and facsimile. The data collection phase of this thesis was complete in mid-November 1997. Forty-six of the sixty-nine project surveys had been returned by e-mail, mail, or fax and were incorporated into the database. Thus the response rate for the second phase of data collection was approximately 66.7%. The willing participation of numerous engineering field divisions and field activities far exceeded the goal of an additional thirty surveys for Part II of the study.

The combined data collection for both Parts I and II was very successful. Fifty-three survey respondents provided data on eighty-five environmental remediation projects. Twenty-one of the respondents requested a copy of the MS Access ® database. Summary tables of the data collected are included in Appendix C.

3.2 Development of a Relational Database

Captain Allen developed a relational database with which to store the project survey data. In Part I of this study, he details the concepts and design of the relational database that he developed using Microsoft ® Access Office 97 version. The query and interface capabilities of the Microsoft ® Office 97 suite later proved invaluable in data analysis.

3.3 Part I Hypotheses

In Part I, Captain Allen recommended the following hypotheses be tested:

1. Projects in which the guidance of the AFCEE remediation technology selection matrix is followed are more successful than those which do not;
2. The great majority (95%) of the technology selection decisions made in military projects are reasonable based on the site characterization;

3. Contract types which assign all risk to the contractor or owner are less successful than risk sharing contractual arrangements; and
4. One reaches a point of diminishing returns in site characterization and study, beyond which project success does not significantly improve.

Part II of the study tested hypothesis Number 1 above. This point correlates to Part II hypotheses Numbers 7 and 8. The remaining hypotheses from Part I are valid and form the nucleus for recommendations for future analysis, Section 5.2.

3.4 Part II Research Scope and Objectives

The scope of Part II of this research was to gather data from U.S. Navy project managers exercising in the field of environmental restoration and compliance. Once the data was collected and organized it was structured for analysis and conclusions were made.

- Sixty-nine surveys sent to numerous Naval Facilities Engineering Command Engineering Field Divisions and Field Offices (Part II)
- Thirty-five Respondents queried (Part II)
- Forty-six Project Surveys returned (Part II)
- Total Respondents: Fifty-three (Parts I and II)
- Total Project Surveys: Eighty-five (Parts I and II)

The objectives of this research were to:

- Collect data from project managers
- Analyze data
- Formulate conclusions and recommendations
- Recommend future analysis

3.5 Data Collection from Project Managers

Project surveys were forwarded to Navy environmental remediation project managers by facsimile, e-mail, and mail after initial contact was made by telephone. Resident Officer in Charge of Construction (ROICC) field offices, Engineering Field Divisions (EFD) and the Navy Engineering Service Center were contacted. Several field offices referred to the Tulsa District, U.S. Army Corps of Engineers. The Army Corps readily responded and provided three project surveys from the Long Horn Army Ammunition Plant

3.6 Database Development

The data was entered into the MS® Access database created in Part I of the study. The data was queried and organized using the query functions of MS® Access and MS® Excel.

3.7 Data Analysis Correlations and Sequence

Figure 3.2 shows the data correlations that are analyzed in this thesis. The project survey generated numerous output variables correlated to project inputs. Input variables are independent of the process. In this thesis, environmental remediation project contaminant, remediation technology, contract type, and site geology are examples of input, or independent, variables. Output variables are dependent upon the process and one or more input variables. Examples in this study are project cost and schedule performance. The first step of analysis was to consider the overall evaluation of projects based on contaminant. Cost and schedule performance was then analyzed versus contaminant. A similar pattern of analysis was followed for "Technologies Selected" and "Reason for Technology

Selection". Conclusions were made based on data presented, comparisons between data sets and from Chi-Square analysis.

After the most significant categories for analysis were determined, the data was presented graphically in the eleven variable relationships shown in Figure 3.2. Statistical analysis followed. The hypotheses proposed are that relationships exist between input and output variables. For example, project cost and schedule performance as well as scope growth versus the type of contaminant, the remediation technology selected, and the reason for technology selection. The null hypotheses tested are that no such relationships exist. The chi-square statistic (χ^2) was used to test for the existence of a relationship between the variables.

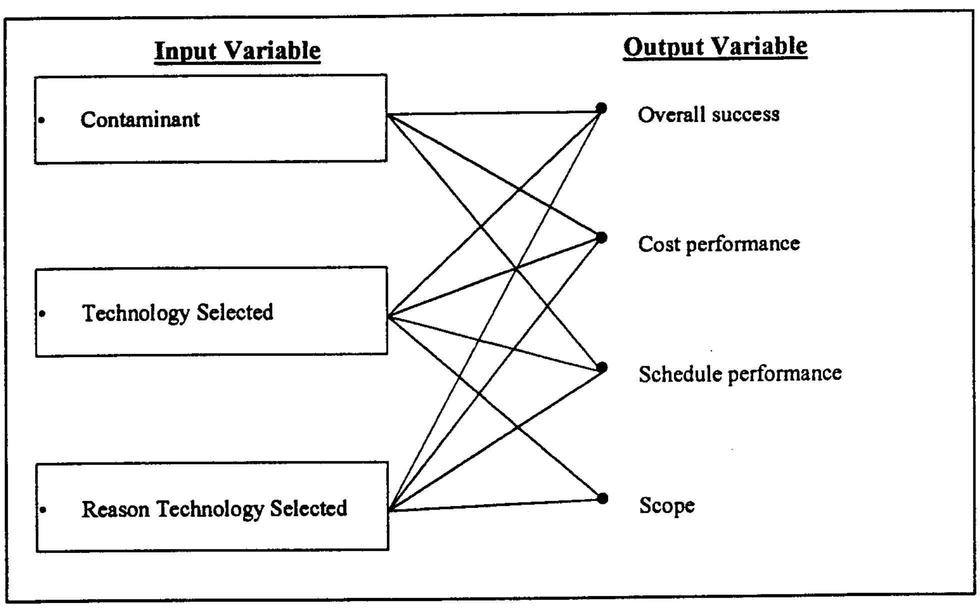


Figure 3.2: Data Correlations Analyzed

The chi-square test is a very general test that is used to evaluate whether or not frequencies which have been empirically obtained, differ significantly from those which would be expected. Contingency tables were then constructed illustrating the cross-classification of data. Table 3.1 is an example of a contingency table for "Cost vs. Contaminant". All of the contingency tables are included in Appendix D.

Cost vs Contaminant

Observed Frequency

	Chlorinated Solvents	Fuel Hydrocarbons	Metals	Other Contaminants	PCBs	Row Total
Over Budget	26.47	36.59	20.83	42.86	36.36	163.11
On /Under Budget	73.53	63.41	79.17	57.14	63.64	336.89
Column Total	100.00	100.00	100.00	100.00	100.00	500.00

Expected Frequency

	Chlorinated Solvents	Fuel Hydrocarbons	Metals	Other Contaminants	PCBs	Row Total
Over Budget	32.62	32.62	32.62	32.62	32.62	163.11
On /Under Budget	67.38	67.38	67.38	67.38	67.38	336.89
Column Total	100.00	100.00	100.00	100.00	100.00	500.00

Chi-Square Terms

	Chlorinated Solvents	Fuel Hydrocarbons	Metals	Other Contaminants	PCBs
Over Budget	1.1600	0.4815	4.2601	3.2113	0.4292
On /Under Budget	0.5616	0.2331	2.0626	1.5548	0.2078

Chi-Square:	14.16
Alpha:	0.001
Critical Value:	18.4662
Decision:	Accept Ho

Table 3.1 Chi-Square Contingency Table

<u>Step One</u>: Compute the expected frequencies on the basis of the assumption that the variables are unrelated using the following formula:

$$f_e = (\text{ column total } * \text{ row total }) / \text{ overall total}$$

Where f_e is the expected frequency.

Step Two: Compute the chi-square terms table using the following formula:

$$\chi^2 = (f_o - f_e)^2 / f_e$$

Where f_o is the observed frequency.

Step Three: Determine the chi-square approximation using the following formula:

$$\chi^2 = \Sigma(f_o - f_e)^2 / f_e$$

Step Four: Determine the critical chi value from a Chi-square distribution table or use the Microsoft ® Excel CHIINV function.

Step Five: Compare the critical chi value to the chi-square approximation determined in Step Three. Reject the null hypothesis if χ^2 is greater than the chi critical value. Do not reject the null hypothesis if χ^2 less than or equal to the chi critical value (Middleton 1995).

The null hypothesis of "no relationship" implies that each population will have the same proportions for each of the categories of the second variable. Looking at the sampling distribution of chi-square can test the null hypothesis. If the value of chi-square is larger than expected by chance, the null hypothesis may be rejected. The significance levels presented indicate the error probability given that the null hypothesis is rejected. Thus smaller significance levels indicated the existence of a possible relationship (Blalock 1979).

3.8 Data Collection

The following is a discussion about the project survey development, data gathered using the project survey, and how it was adapted for analysis. The background on several questions and the reasons for certain steps in data preparations are explained.

Captain Allen recommended in his thesis presentation that certain changes be incorporated in the project survey. The words "hazardous waste" were removed from the title to avoid confusion and sync with the Environmental Protection Agency's explicit definition. Since the word "failure" was considered to be "too strong" in the "key factors" question on the second page, the survey was changed to ask about the "impact of key factors on project outcome (1-positive, 2-no major impact, 3-negative, 4-N/A)." The final recommendation to number the questions on the survey was not incorporated and was never an issue. The discussion continues with background information for one survey question.

The project survey question "What is the primary reason (or combination of reasons) for technology selection?" offered six selections for the respondent to choose. The first one was "Air Force Guidance" which correlates to the first hypothesis in Part I of this study: "That projects in which the guidance of the AFCEE remediation technology selection matrix is followed are more successful than those which do not." Part II of the study focused on data collection from the U.S. Navy so the response selection on the survey was changed to read "NAVFAC Guidance." NAVFAC does not utilize the Air Force decision selection matrix so the response to this question could not be combined into an overall category such as "Sponsor Guidance." NAVFAC has a general policy that innovative technologies should be utilized in an effort to optimize schedule and cost performance but does not adhere to a strict decision matrix (DON 1996). Thus, this study will address the use of the AFCEE remediation technology decision matrix and its effectiveness as a primary reason for technology selection. The next two sections will describe data that fell into the "Other" categories.

The "Other Technology" category has twenty-six projects in it. Five of the projects used a combination of technologies generally associated with land disposal. This category of "Other Technologies" includes many innovative means for environmental clean up and compliance, including: underground storage tank and fuel piping removal, resin adsorption vapor treatment, base catalyzed decomposition, and recycling various material for asphalt concrete.

The "Other Contaminants" category is associated with fifteen projects. Seven projects have one type of contamination not falling into one of the four major categories while eight have a combination of contaminants. Generally, the "Other Contaminants" are: pesticides, low level radioactive waste, lead, asbestos, and explosives.

Data was arranged for graphical presentation increasing from left to right with the "good" category in the series to the rear. The author did this since the "good" category was almost always numerically greater than the "bad" category and the graph was therefore easier to read. The "good" category is typically series such as "On Budget", "Ahead or On Schedule", or "Successful". The next two sections discuss data not utilized due to insufficient sample size and grouping data into larger categories.

Some data could not be analyzed due to insufficient response in that particular category. Respondents were given full latitude to select the projects that they reported on although they were requested to try to give a quality spread with one project considered highly successful, one project considered typical, and one project below their expectations. Several of the remediation technology categories did not have enough data to be statistically valid.

Technologies dropped include:

Passive Treatment Wall	Bioventing
Chemical Oxidation / Reduction	Incineration

Much of the data gathered on the Project Survey was suitable for grouping prior to analysis. The data was grouped for several reasons. First, there was a very fine line in distinction between alternatives for respondents to select on some of the subjective questions. And second, grouping simplified and clarified analysis. Three categories of data were grouped during this analysis: 1) "Successful" and "Acceptable" were grouped in the project's overall assessment . This was grouped because the survey did not present sufficient ranking criteria or structure to differentiate the two. Additionally, "Acceptable" implies a success… the two are very nearly the same. 2) "Ahead" and "On schedule" were grouped because "On schedule" is good and "Ahead of schedule" is generally accepted as good also. 3) "No change" and "Decreased scope" were grouped because "No change" in scope suggests that the scope definition was good and "Decreased scope" is generally accepted as good.

The data collection tool, while itself concise, generated far more areas of study than can be adequately addressed in one thesis presentation. The data collected are included in Appendix C. The names and telephone numbers of the individual survey participants are not provided in this thesis for confidentiality. The next two sections propose future analysis. The first section centers on a wealth of subjective data on factors impacting project outcome. The respondent was requested to rank fourteen items one to four using the following scale:

1 – Positive	2 – No major impact
3 – Negative	4 – Not applicable

The second section is a good follow-on to analysis in this thesis considering contract issues, geotechnical issues, and clean-up standards versus overall success, cost and schedule performance, and scope change.

3.9 Recommended Future Analysis

Data items not considered in this analysis but reserved for possible future analyses include the following:

Input Variables	Output Variables
Sources of funding	Operations and maintenance costs
Estimated contract cost	Percentage complete (to date)
Project duration	
Reuse plans for the site	
Impact on project outcome	

- Project planning / Funding
- Political involvement
- Laboratory analysis / Sampling plan & methods
- Implementation contract type / Contractor performance
- Team building & partnering / Contract disputes
- Severe weather / Contract incentives
- Discovered more contamination
- Unanticipated soil, geological or ground water conditions
- Technology performance

Data analyses considered particularly valuable but reserved for future analyses are shown in Figure 3.3. The entire spectrum of contract type is useful

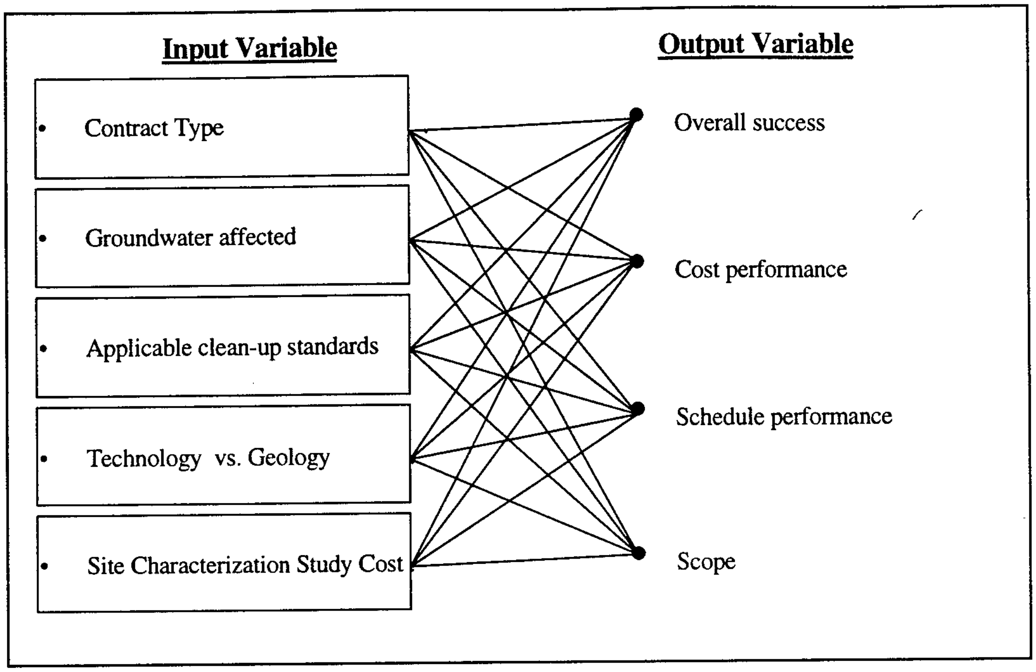


Figure 3.3: Correlations Recommended for Future Analyses

to consider when faced with an environmental compliance requirement. Ground water and site geology analysis could yield indicators of success in one remediation technology over another. The clean-up standards that are applied by various agencies vary, can affect project success, and are certainly worthy of analysis. The evolution of site characterization costs is valuable to consider for many reasons. One could determine whether there are trends over the past fifteen to twenty years showing that pre-project planning is paying off and in what particular arena. Perhaps more importantly, one may determine if the Department of Defense is getting better at dealing with environmental issues.

The next chapter covers data analysis. Again, Figure 3.2 illustrates the sequence of analyses and is a ready reference guide through Chapter 4.

Chapter 4. Data Analysis

4.1 Project Performance versus Contaminant

The vast majority of the projects, 97.7% were evaluated as successful. As shown in Figure 4.1, only two of eighty-five projects in the sample were rated unsuccessful.

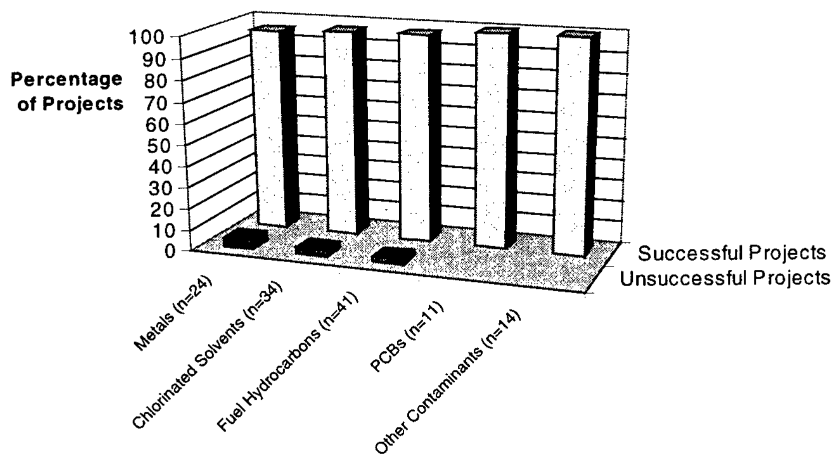


Figure 4.1: Overall Performance vs. Contaminant Type

The overwhelming survey response with successful projects may in part be due to respondents' natural tendency to report on successes rather than failures even though a quality spread was requested. Table 4.1 details contaminant type in the unsuccessful projects. Project "A" had fuel hydrocarbon contamination and Project "B" had a combination of fuel hydrocarbon, chlorinated solvents, and metals. Both projects were over-budget, behind schedule, and their scope increased. The final question on the project survey was an overall evaluation of the project results to date. The respondent was given three categories from which to select a response:

- Successful
- Acceptable
- Unsuccessful

As discussed in Section 3.7, "Successful" and "Acceptable" were grouped together to clarify analysis. In retrospect, providing a better metric for response to this question would have significantly increased the value of the data. The following two sections show that while, for the data gathered, fuel hydrocarbons were present in a significant number of projects associated with poor cost and schedule performance, statistical analysis shows in both cases that there is no relationship between cost or schedule performance and contaminant type.

Contaminant Present	Unsuccessful Project "A"	Unsuccessful Project "B"
Other Contaminants (n=14)		
Fuel Hydrocarbons (n=41)	X	X
PCBs (n=11)		
Chlorinated Solvents (n=34)		X
Metals (n=24)		X

Table 4.1: Contaminants Present in Unsuccessful Projects

4.2 Cost Performance versus Contaminant

The data shown in Figure 4.2 suggest that there are few budget certainties in environmental restoration and compliance projects.

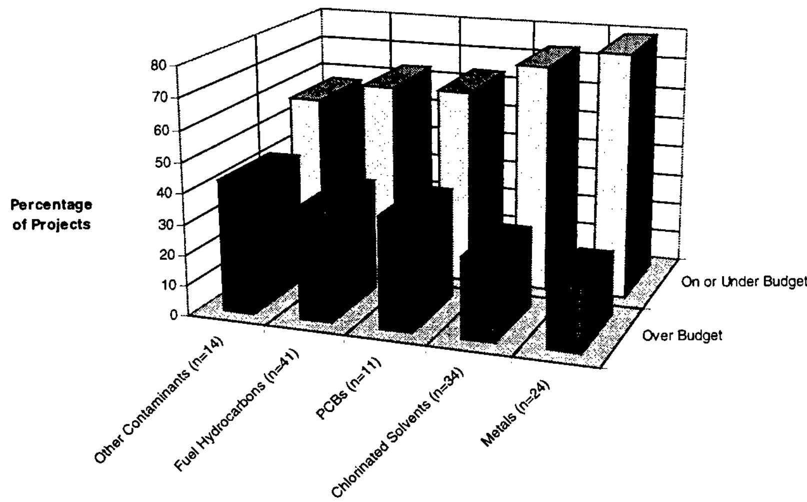


Figure 4.2: Cost Performance vs. Contaminant Type

Overall twenty-nine of the eighty-five, or 34.1% of the projects sampled were over budget. Projects with metal contaminants performed best. Both "Fuel Hydrocarbons" and "Other Contaminants" categories performed lower than average for the sample set when considering cost performance. While graphically it appears that projects with metal contaminants perform better than other contaminants, chi-square statistical analysis shows that project cost performance in general *does not* vary with contaminant type. The contingency tables that support the chi-square analysis of the null hypothesis are included in Appendix D, Table D-1.

Specific observations include the following:

- Metals - Five of twenty-four or 20.8% over budget
  - Associated data show that scope increased on four of the five projects over budget.
- Fuel Hydrocarbons - Fifteen of forty-one, or 36.6% over budget
  - Scope increased on seventeen of the forty-one projects. Not all of the budget overruns are possibly attributed to scope growth though as only twelve of those were over budget (29.3% of the total).
- Other Contaminants - Six of fourteen or 42.9% over budget
  - Scope increased on nine of fourteen projects, six of which were over budget (42.9% of the total).
  - As discussed in Section 3.8, contaminants in this category include pesticides, low level radioactive waste, lead, asbestos, and explosives which coupled with scope growth may explain the over-budget cost performance.

4.3 Schedule Performance versus Contaminant

The data shown in Figure 4.3 suggests that four of the five categories performed satisfactorily "Ahead or On Schedule" 73% to 82% of the time. Overall sixty-three of the eighty-five, or 74.1% of the projects sampled were "Ahead or On Schedule" schedule. "Chlorinated Solvents" were the best performers while both the "Fuel Hydrocarbons" and the "Other Contaminants" categories performed lower than average for the sample set. While graphically it appears that projects with chlorinated solvent contaminants perform better regarding schedule than other contaminants, chi-square statistical analysis shows that project schedule performance in general *does not* vary with contaminant type. The contingency tables that support the chi-square analysis of the null hypothesis are included in Appendix D, Table D-2.

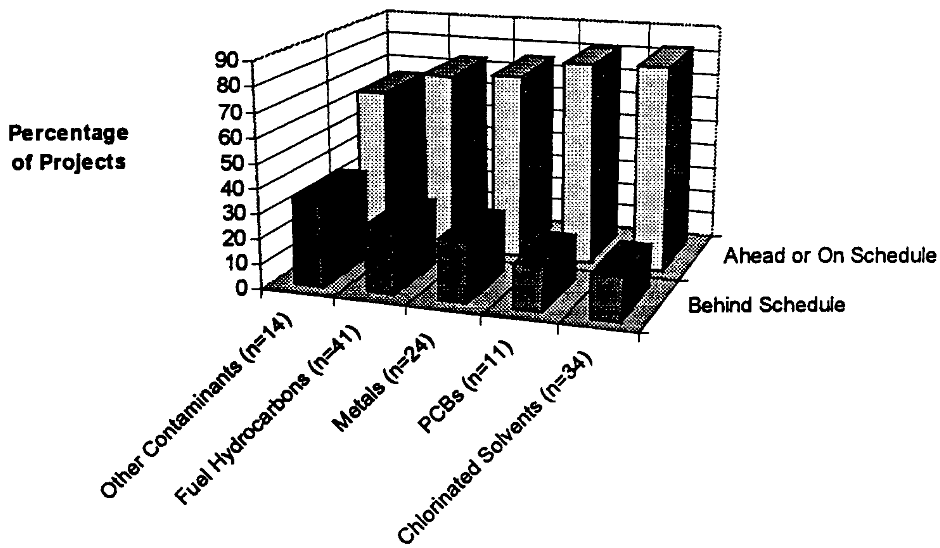


Figure 4.3: Schedule Performance vs. Contaminant Type

Specific observations include the following:

- Chlorinated Solvents – Six of thirty-four or 17.7% behind schedule.
  - Four of these six had scope growth.

- PCBs – Two of eleven or 18.2% behind schedule.
- Metals – Six of twenty-four or 25% behind schedule.
- Fuel Hydrocarbons – Eleven of forty-one or 26.7% behind schedule.
- Other Contaminants - Six of fourteen or 42.9% behind schedule.
  - Scope increased on nine projects, six of which were over budget (42.9% of the total).
  - As discussed in Section 3.8, contaminant types in this category include pesticides, low level radioactive waste, lead, asbestos, and explosives which coupled with scope growth may explain this over budget cost performance.

4.4 Project Performance versus Technology Implemented

The project survey identified eleven specific environmental remediation technologies and allowed the respondent to pencil in any additional innovative technologies that may have been utilized:

Soil vapor extraction	Passive treatment wall
Air sparging	Low permiability soil cap
Biodegradation	Goundwater pump and treat
Bioventing	Excavation and incineration
Chemical reduction / oxidation	Excavation and land disposal
Composting	And several innovative technologies

Bioventing, composting, treatment wall, incineration, and chemical oxidation / reduction are not considered in this study due to insufficient sample population in the response to the survey. Project cost and schedule performance as well as scope change and overall evaluation will be addressed in this section.

4.5 Overall Project Evaluation versus Technology Implemented

All but two of the eighty-five projects surveyed were judged by the survey respondents to be successful.

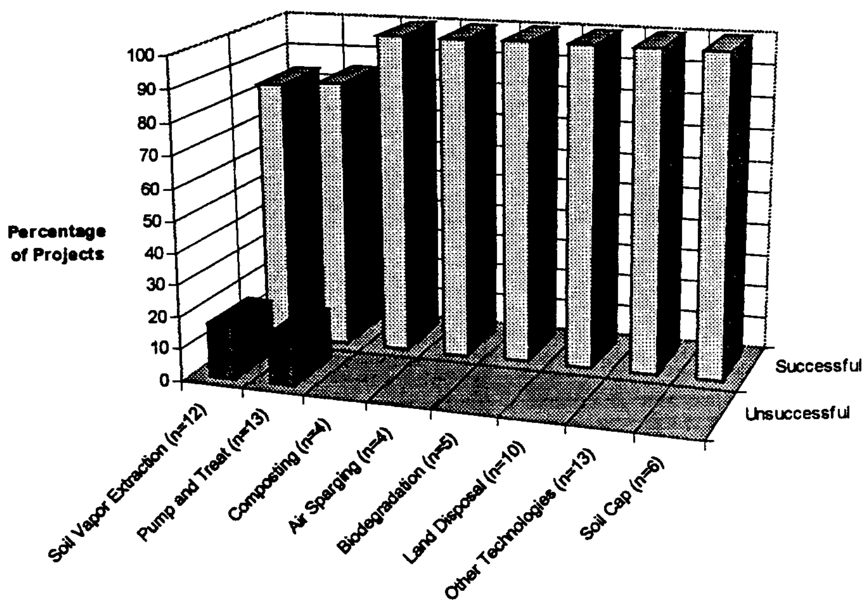


Figure 4.4: Overall Project Results vs. Technology Implemented

One soil vapor extraction project and one pump-and-treat project were over budget, behind schedule, and increased in scope more than 5%. Their project manager judged both projects unsuccessful. As discussed in Section 4.1, clearer definition of a more refined metric would have produced more valuable data in this category. Figure 4.4 displays this data graphically.

4.6 Cost Performance versus Technology Implemented

Figure 4.5 illustrates that seven of eight remediation technologies performed well being on or under budget between 66.7% and 100% of the time.

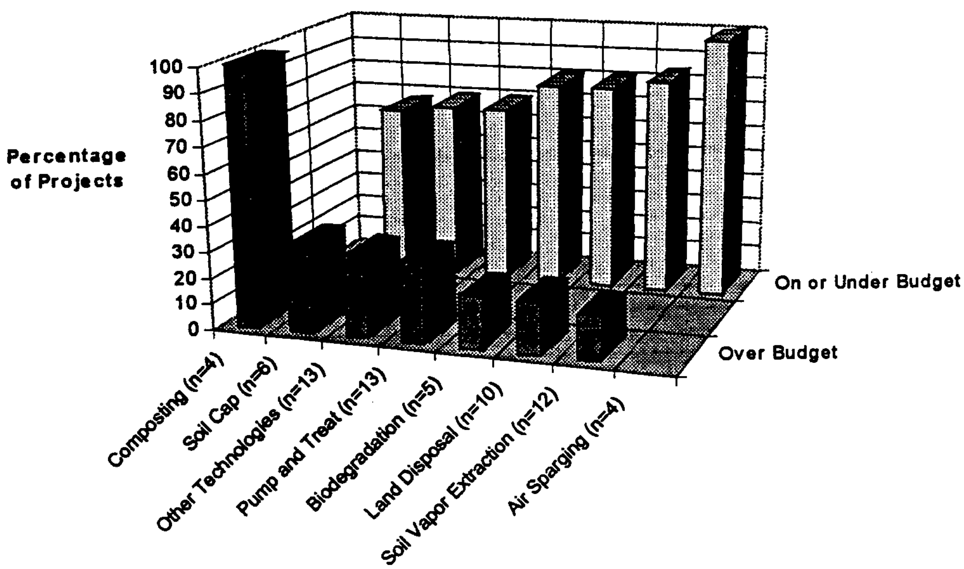


Figure 4.5: Cost Performance vs. Technology Implemented

"Composting" performed poorly with all four of the projects in the sample group over budget. While four projects in each category is a small sample size, two technologies stand out in their cost performance. "Air Sparging" performed particularly well with dissolved fuel or dissolved chlorinated solvents in ground water and "Composting" performed poorly from the sample set with fuel contaminated soil. Statistical analysis supports the graphical representation in Figure 4.5 that suggests that some remediation technologies are better than others in cost performance. Chi-square analysis rejects the null hypothesis and supports the alternate hypothesis that project cost performance *does vary* with technology implemented. The contingency tables that support the chi-square analysis of the null hypothesis are included in Appendix D, Table D-3.

Specific observations include the following:

- "Soil Vapor Extraction" - Two of twelve or 13.7% of the projects were over budget.
- The best performer was "Air Sparging" with 100% of the four projects on or under budget.
- All four projects utilizing "Composting" were over budget.
  - Associated data shows that three of the four projects were also behind schedule and three of the four (not the same three) increased in scope more than 5%.
- "Low Permeabilitiy Soil Cap" - Two of the six, or 33.3% of the projects were over budget.
- "Other Technologies" - Four of thirteen or 30.8% of the projects were over budget.
  - As described in Section 3.8, often developing or innovative technologies were in this category. Five such projects which were a combination of technologies generally associated with land disposal and underground storage tank and fuel piping removal, resin adsorption vapor treatment,

base catalyzed decomposition, and recycling various material for asphalt concrete were over budget.

4.7 Schedule Performance versus Technology Implemented

The data in Figure 4.6 illustrates that five of the eight remediation technologies performed well being ahead or on schedule between 76.9% and 100% of the time.

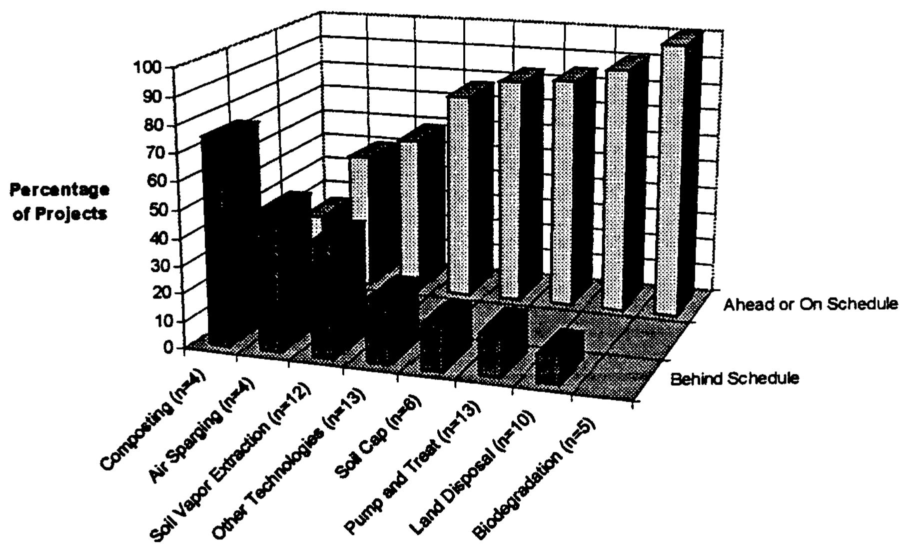


Figure 4.6: Schedule Performance vs. Technology Implemented

Land disposal and biodegradation were the top performers while soil vapor extraction, composting, and air sparging were the poorest. Statistical analysis supports the graphical representation in Figure 4.6 that suggests that some remediation technologies are better than others in schedule performance. Chi-square analysis rejects the null hypothesis and supports the alternate hypothesis that project schedule performance *does vary* with technology implemented. The contingency tables that support the chi-square analysis of the null hypothesis are included in Appendix D, Table D-4.

Specific observations include the following:

- Nine of the ten "Land Disposal" and five of five "Biodegradation" projects were ahead or on schedule.
- "Composting" – Three of the four, or 75%, of the projects were behind schedule.
- "Air Sparging" - Two of the four, or 50%, of the projects were behind schedule.
- "Soil Vapor Extraction" - Five of the twelve, or 41.7%, of the projects were behind schedule.

Schedule and cost performance on the four projects utilizing "Composting" may be tied together. All four projects were over budget and three of the four were behind schedule.

4.8 Scope Change versus Technology Implemented

The data in Figure 4.7 illustrates that project scope increased between 30% and 50% in the best performing six remediation technologies implemented. The series displayed in Figure 4.7 is bracketed by two technologies that had a much smaller sample size of four projects each. While four projects in each category is a small sample size, two technologies stand out in their change in scope. "Air Sparging" performed particularly well with dissolved fuel or dissolved chlorinated solvents in ground water and "Composting" performed poorly from the sample set with fuel contaminated soil. Statistical analysis supports the graphical representation in Figure 4.7 that suggests that some remediation technologies are better than others in scope change. Chi-square analysis rejects the null hypothesis and supports the alternate hypothesis that project scope change *does vary* with technology implemented. The contingency tables that support the chi-square analysis of the null hypothesis are included in Appendix D, Table D-5.

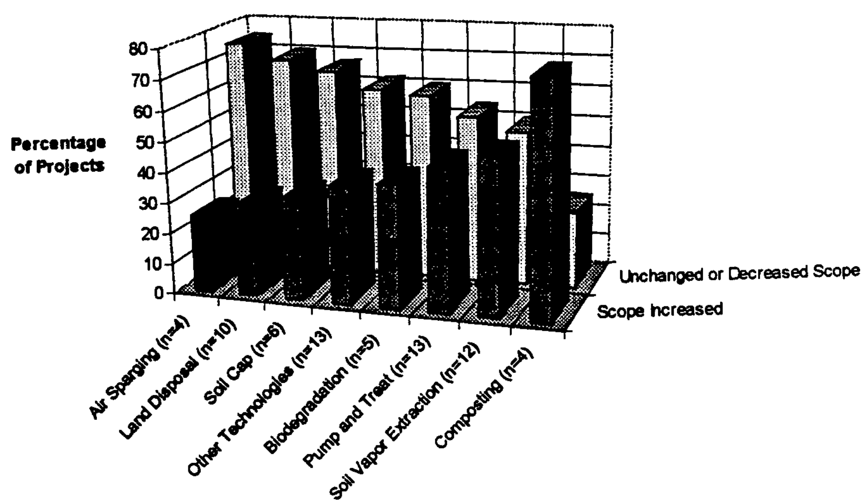


Figure 4.7: Scope Change vs. Technology Implemented

Specific observations include the following:

- "Air Sparging" - One of four, or 25% of the projects increased in scope.
- "Land Disposal" - Three of ten, or 30% of the projects increased in scope.

- "Pump and Treat" - Six of thirteen, or 46.2% of the projects increased in scope.
- "Soil Vapor Extraction" - Six of twelve, or 50% of the projects increased in scope.
- "Composting" – Three of four, or 75% of the projects increased in scope.

4.9 Performance versus Reason for Technology Selection

This section presents an analysis of project performance in cost, schedule, scope change, and overall success versus the reason the program manager selected the particular remediation technology. The survey addressed six major reasons why program managers selected a specific remediation technology:

- Selection may be based on guidance from AFCEE or NAVFAC.
- "Regulatory requirements" may dictate a specific technique.
- "Minimal Exposure Hazard" may be a concern.
- "Cost"minimization.
- "Schedule" maintainability or quick turn-around.
- "Effectiveness" of the technology.

Section 3.8 covers in detail what is meant by AFCEE or NAVFAC guidance. The Air Force has developed a decision matrix for remediation technology selection. Part of this study is to validate that matrix.

4.10 Overall Project Evaluation versus Reason for Technology Selection

The project survey queried the respondent's "Evaluation of overall project results to date" and allowed the respondent to select one of three categories: a) Successful, b) Acceptable, or c) Unsuccessful.

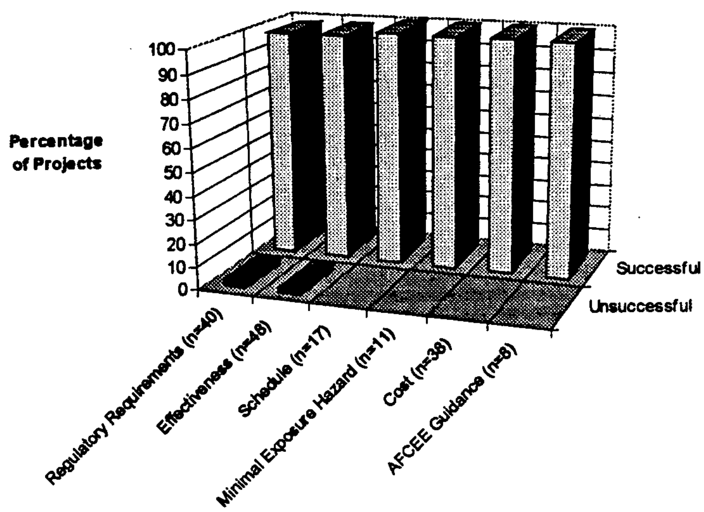


Figure 4.8: Overall Results vs. Reason for Technology Selection

Figure 4.8 illustrates overall project results versus each of the six categories that survey respondents selected as the primary reason or combination of reasons for technology selection. All six categories were graded exceptionally well. Overall there were only two of eighty-five projects or 2.4% marked unsuccessful. Each of these projects was behind schedule, over budget, and the scope had increased.

The data supports the first hypothesis from Part I of this study, but overall the results may be inflated. Grade inflation may be a combination of an insufficient scale on the project survey attempting to quantify this subjective data and the survey respondents desire to inflate overall project evaluation. It is only natural to want to point out one's successes rather than one's lesser performance.

When schedule, cost, and scope are considered with the overall project evaluation, from a combined perspective, the data supports: "that projects which utilize the AFCEE remediation technology selection matrix were more successful than those which do not". As discussed in Sections 4.1 and 4.5, clearer definition of a more refined metric would have produced more valuable data in this category.

4.11 Cost Performance versus Reason for Technology Selection

The project survey queried project cost and allowed the respondent to select one of three categories: a) Under budget (2% or more), b) On budget, or c) Over budget (2% or more). Figure 4.9 illustrates cost performance versus each of the six categories that survey respondents selected as the primary reason or combination of reasons for technology selection. Generally, five categories performed in an acceptable range being on budget between 67.6% and 75% of the projects studied. When "Schedule" was selected as a reason for the project's technology selection, the overall results were below average. Graphically it appears that projects, which used AFCEE guidance or effectiveness to select the remediation technology to be implemented, performed best regarding cost. Chi-square statistical analysis shows that project cost performance in general *does not* vary with reason for technology selection. The contingency tables that support the chi-square analysis of the null hypothesis are included in Appendix D, Table D-6.

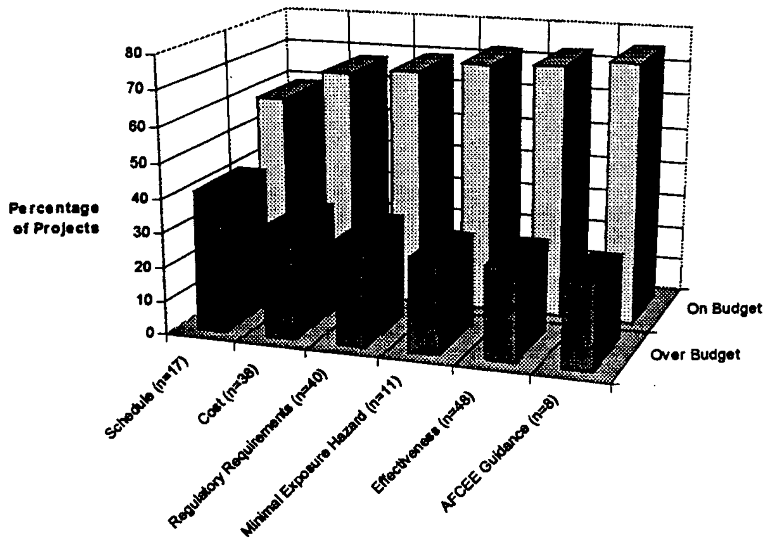


Figure 4.9: Cost Performance vs. Reason for Technology Selection

Specific observations include the following:

- When "Schedule" was selected as a reason for the project's technology selection, projects were only on budget 10 of 17 or 58.8% of the time.
  - Project duration or schedule may have been more important than cost and the project manager may have allowed the cost to creep up in order to maintain schedule.
- When "Cost" was a technology selection criteria, projects came in on budget 67.6% of the time.
  - Twenty-one of the thirty-eight projects addressed fuel hydrocarbon or a combination of fuel and other contaminants. Eight of twelve, or 66.7%, of the over budget projects were to remediate fuel contamination.
  - Four of the twelve, or 33.3% of the over budget projects were to remediate chlorinated solvents.

- "Composting" and "Land Disposal" were the predominant remediation technologies in these projects.

- When "Regulatory Requirements" was a technology selection criteria, projects came in on budget 69.2% of the time.
- When "Minimal Exposure Hazard" was a technology selection criteria, projects came in on budget 72.3% of the time.
- "Effectiveness" of the technology is probably the strongest selection reason with 72.9% of the large, 48 project, sample being on budget.
  - This reason was most often cited as the reason that a project manager selected a particular technology. "Effectiveness" was selected 56.5% of the time.
  - When the technology is selected based on how well it performs, tried and true methods deliver in the majority of the cases sampled.
- Projects that utilized the AFCEE technology selection matrix in determining which remediation technology to utilize were successfully on budget 75% of the time.

Using the AFCEE selection matrix as the primary reason for technology selection was the best overall selection criterion for this data sample. This area of analysis confirms part of the first hypothesis from Part I.

4.12 Schedule Performance versus Reason for Technology Selection

The project survey queried project schedule performance and allowed the respondent to select one of three categories: a) Ahead of schedule (2% or more), b) On schedule, or c) Behind schedule (2% or more).

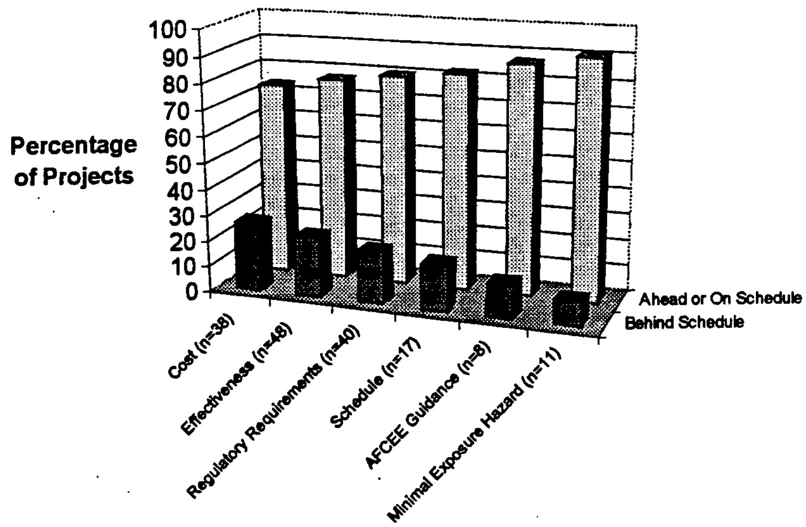


Figure 4.10: Schedule Performance vs. Reason for Technology Selection

The data illustrated in Figure 4.10 shows schedule performance versus each of the six categories that survey respondents selected as the primary reason or combination of reasons for technology selection. Generally, all six categories performed in an acceptable range being on schedule between 73.7% and 90.9% of the projects studied. Graphically it appears that projects, which used minimal exposure hazard or AFCEE guidance to select the remediation technology to be implemented, performed best regarding schedule. Chi-square statistical analysis shows that project schedule performance in general *does not* vary with reason for technology selection. The contingency tables that support the chi-square analysis of the null hypothesis are included in Appendix D, Table D-7.

Specific observations include the following:

- The most outstanding categories in this sample were "Minimal Exposure Hazard" and "AFCEE Guidance" which were ahead or on schedule 90.9% and 87.5% for the eleven and eight projects respectfully. When the program manager selected a remediation technology to address one of these criteria, he was typically dealing with the following type projects:
  - Six of the eight projects that utilized the "AFCEE Guidance" had fuel hydrocarbon or a combination of fuel and other contaminants.
  - The Air Force projects did not utilize "Composting" but used "Soil Vapor Extraction", "Biodegradation", "Bioventing", and in one case "Land Disposal".
  - Six of the eleven projects, or 55%, that utilized the "Minimal Exposure Hazard" " as a remediation technology (and used "Cost" as a technology selection criterion) addressed a chlorinated solvent contamination. Four of these six, or 36% of the projects were for metal contamination. Land disposal or soil cap were used almost exclusively.
- Projects that selected a technology specifically for "Schedule" concerns came in ahead or on schedule fourteen of seventeen or 82.3% of the time ranking third overall.
- The low end of the spectrum were projects with technology selected based on "Cost" which still produced a satisfactory twenty-eight of thirty-eight or 73.7% ahead or on schedule. When the program manager selected a technology based on cost control, there are several reasons that relate to poor schedule performance:
  - Twenty-one of the thirty-eight projects that were behind had fuel hydrocarbons or a combination of fuel and other contaminants. Six of these twenty-one, or 29% were behind schedule.

- Four of the ten projects that were behind schedule were utilizing innovative technologies. Two of these projects were using processes that are preliminary to "Composting".
- Three of four projects, or 75%, that utilized "Composting" as a remediation technology (and used "Cost" as a technology selection criterion) were behind schedule.
- Three of seven projects, or 40%, that utilized "Soil Vapor Extraction" as a remediation technology (and used "Cost" as a technology selection criterion) were behind schedule.

This data suggests that "Composting" does not have as effective cost control as other remediation technologies and is a slower process than originally programmed thus additional time is required during project execution. "Composting" should not be selected as a remediation technology if schedule and cost are important. This data is also associated with analysis in Section 4.7 showing "Soil Vapor Extraction" projects to be behind schedule on five of twelve, or 41.7% of the time. This correlation suggests that while "Soil Vapor Extraction" is a good performer for cost control, it is not good in schedule performance.

Using the AFCEE selection matrix as the primary reason for technology selection was a strong performer for this data sample. This area of analysis confirms part of the first hypothesis from Part I.

4.13 Scope Change based on Reason for Technology Selection

The project survey queried project scope change and allowed the respondent to select one of three categories: a) Increased scope (5% or more), b)

No change, or c) Decreased scope (5% or more). The data in Figure 4.11 illustrates scope change versus each of the six categories that survey respondents selected as the primary reason or combination of reasons for technology selection. Scope change is common place in environmental remediation projects due to the inherent uncertainty associated with unknown and underground conditions. A project whose scope increases is not necessarily considered unsuccessful. In fact, the scope increased on fifty-two of eighty-five or 61.2% of the projects surveyed yet only two projects were reported unsuccessful. Statistical analysis supports the graphical representation in Figure 4.11 suggesting that some reasons for selecting a remediation technology are better than others in scope definition. Chi-square analysis rejects the null hypothesis and supports the alternate hypothesis that project scope performance *does vary* with reason for technology selection. The contingency tables that support the chi-square analysis of the null hypothesis are included in Appendix D, Table D-8.

Specific observations include the following:

- Both of the unsuccessful projects were over budget, behind schedule, and the scope increased.
- Scope control as an output of the reason for technology selection is best afforded when "Schedule" or "Effectiveness" of technology is most important.
  - "Effectiveness" - Three of forty-eight, or 6.25% increased scope.
  - "Schedule" - Three of seventeen, or 17.7% increased scope.
- "AFCEE selection criterion" - two of eight, or 25% increased scope.
- "Cost" – Nineteen of thirty-eight projects, or 50% increased in scope.

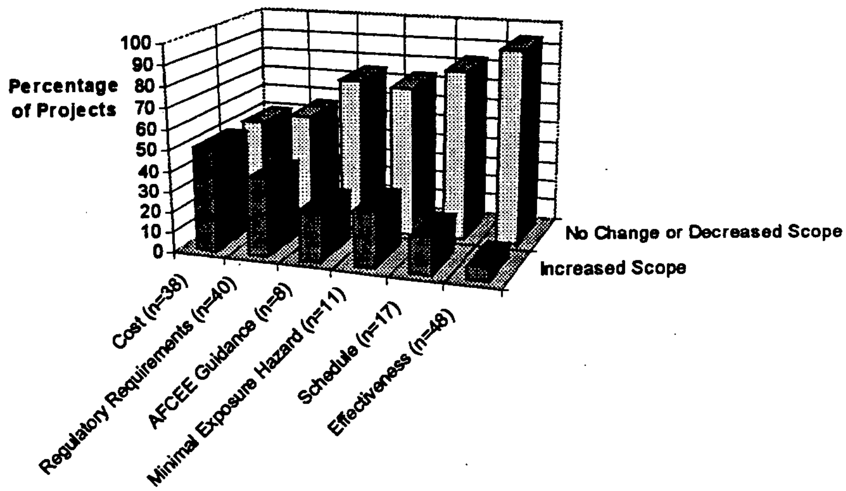


Figure 4.11: Scope Change vs. Reason for Technology Selection

This may not be cause for alarm when correlated with other survey data. None of the projects marked "unsuccessful" by survey respondents used cost as a primary reason for technology selection. Only nine of the nineteen projects that experienced scope growth were over budget. In this category there are thirty-eight projects which considered "Cost" as a primary reason for technology selection. Nine projects, or 23.7% experienced scope growth coupled with being over budget. This cost performance coupled with scope increases is considered to be within satisfactory bounds. When the overall project rating and budget concerns are considered in concert with the scope change, the data suggests that project controls were successful when "Cost" was considered important. The next chapter presents the study conclusions and recommendations.

Chapter 5 Conclusions and Recommendations

5.1 Conclusions

This chapter completes the study by summarizing the hypotheses and then presentation of conclusions and recommendations. The following hypotheses were proven in this thesis:

1. That project cost performance *does vary* with technology implemented.
2. That project schedule performance *does vary* with technology implemented.
3. That project scope performance *does vary* with technology implemented.
4. That project scope performance *does vary* with reason for technology selection.

This thesis demonstrates that steps in planning environmental restoration and compliance projects can increase the likelihood of successful project performance. Specifically, careful consideration of the reason for technology selection and the actual technology selected can greatly effect project outcome in schedule and cost performance. Both the Department of Defense Technology Selection Matrix and the Air Force Center for Environmental Excellence Remediation Matrix are effective decision making tools to help select the appropriate remediation technology although they do not in themselves guarantee success. These tools are certainly recommended for the inexperienced project manager. Additional hypotheses also proven in this thesis follow:

5. That project cost performance *does not vary* with contaminant type.
6. That project schedule performance *does not vary* with contaminant type

7. Project schedule performance *does not vary* with reason for technology selection.
8. Project cost performance *does not vary* with reason for technology selection.

The following conclusions are in addition to the proven hypotheses:

1. That in general the AFCEE selection matrix is a valuable tool in determining which remediation technology to utilize.
2. That while the Air Force pushes composting in the AFCEE matrix it was a poor performer in this sample group.

5.2 Recommendations

The following recommendations were developed during analysis and evaluation in this thesis:

1. That further study be conducted using the abundant, valuable data already gathered on the project survey and formulated in the database. The most valuable data relationships to consider are shown in Figure 3.3. Contract type, groundwater problems, applicable clean-up standards, technology compared to geology, and site characterization study costs can all be compared to overall project success, project cost and schedule performance, and project scope changes.

2. That additional data should be gathered to specifically address the question of DOD performance in site characterization. A study of the evolution of site characterization costs could determine whether there are trends over the past fifteen to twenty years showing that pre-project

planning is paying off and in what particular arena. More importantly, one may determine if the Department of Defense is getting better at dealing with environmental issues and also whether the costs of the study produce sufficient benefit to justify continued expenditures.

3. That should additional data be gathered using this project survey tool or one similar to it, the question of an overall project evaluation should be refined and a better metric should be developed. The metric could build on a scale of one to five and give quantifiable items for the respondent to consider. Successful projects would be graded five and unsuccessful projects graded one. Acceptable projects would be defined as a grade of three. The respondent would be asked to subtract one point if the project was behind schedule 2% or more and subtract one point if the project was over budget 2% or more. Other similar quantifiable items could be defined or the balance of the grade could be left to the respondent's subjective evaluation. The end result would be much more valuable data for project performance analysis.

4. That a systems engineering approach should be used in the remediation technology selection process. That is, decisions should be made using some sort of proven decision-making matrix such as the Department of Defense Remediation Technologies Screening Guide, Table 2.1 or the Air Force Center for Environmental Excellence Remediation Matrix-Hierarchy of Preferred Alternatives, Table 2.2. Both tables have been developed with process improvement and feedback loops to self-improve.

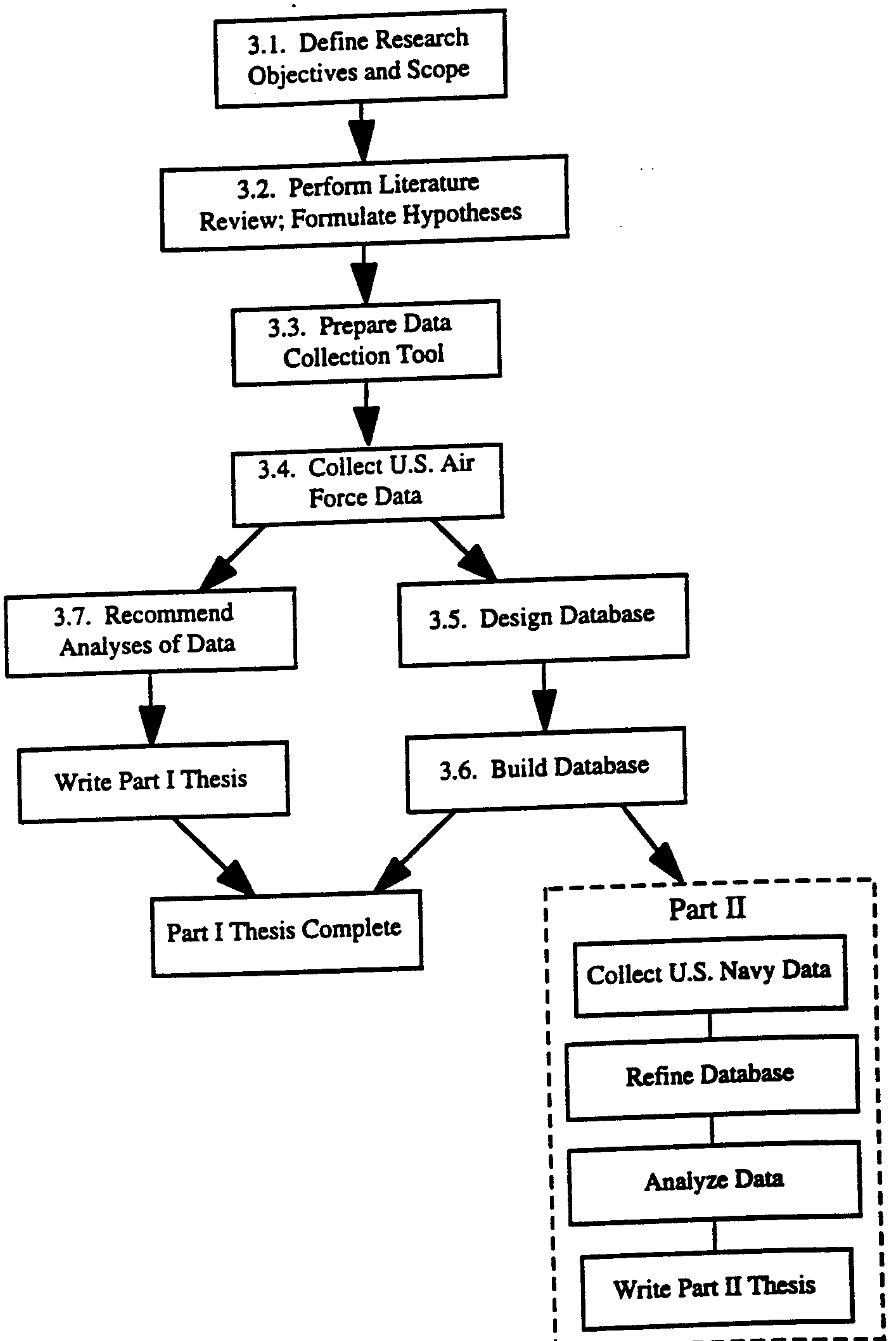
This concludes the written portion of this thesis. Following are various appendices including data and analysis tables, then bibliography, and vita.

<u>Appendices</u>

Appendix A

Research Plan from Part I

The following figure is the work of Captain Scot T. Allen USAF.


3.1. Define Research Objectives and Scope
3.2. Perform Literature Review; Formulate Hypotheses
3.3. Prepare Data Collection Tool
3.4. Collect U.S. Air Force Data
3.7. Recommend Analyses of Data
3.5. Design Database
Write Part I Thesis
3.6. Build Database
Part I Thesis Complete
Part II
Collect U.S. Navy Data
Refine Database
Analyze Data
Write Part II Thesis

Appendix B

Data Collection Tool

The following survey is the work of Captain Scot T. Allen USAF.

Please fill out and return to: LT Joseph A. Campbell
Department of Civil Engineering, CEPM
jacampbell@mail.utexas.edu
The University of Texas
Austin TX 78712-1076

Tel: (512) 331-8899
E-mail:

Fax: (512) 471-3191

Environmental Site Remediation Project Survey

Name: ____________________ Fax: ______________ Date: _____

Agency/Unit: ____________________ Project Name: ____________________

Telephone: ____________________ Project Location (Base, City, State): _____

E-mail: ____________________ ____________________

The Problem:

Contaminants present (check all that apply):
- ❑ Fuel hydrocarbons
- ❑ Chlorinated solvents
- ❑ Metals
- ❑ PCB's
- ❑ Other: ______________

Maximum depth of contamination:
- ❑ 0-10 feet
- ❑ 11-20 feet
- ❑ 21-30 feet
- ❑ 31-40 feet
- ❑ 41-50 feet
- ❑ Over 50 feet

Contamination has affected (all that apply):
- ❑ Soil
- ❑ Groundwater
- ❑ Air

If groundwater is affected, contaminants are (check all that apply):
- ❑ Dissolved in groundwater
- ❑ Free product (Non-Aqueous Phase Liquid, NAPL)

If groundwater is affected, the plume:
- ❑ extends beyond the property line
- ❑ is completely on site
- ❑ has an unknown extent

Average depth to the water table:
- ❑ 0-10 feet
- ❑ 11-20 feet
- ❑ 21-30 feet
- ❑ 31-40 feet
- ❑ 41-50 feet
- ❑ Over 50 feet

Soil/geology classification (check the most important sit features):
- ❑ Tight clay/silt (impermeable soils)
- ❑ Loose sand/gravel (permeable soils)
- ❑ Relatively impermeable bedrock (e.g. solid granite)
- ❑ Permeable bedrock (e.g. fissured limestone)

Site is planned for reuse:
- ❑ In 1-3 years
- ❑ In 4-10 years
- ❑ No definite plans (or no information)

The Solution:

Remediation technology selected (please indicate combinations):
- ❑ Soil vapor extraction (SVE)
- ❑ Air sparging (*in situ*)
- ❑ Biodegradation (except bioventing)
- ❑ Bioventing
- ❑ Chemical Oxidation/Reduction
- ❑ Composting or Land Farming
- ❑ Excavation and land disposal
- ❑ Excavation and incineration
- ❑ Low Permeability Soil Cap
- ❑ Passive Treatment Wall
- ❑ Pump and treat (*ex situ* air stripping)
- ❑ Other: ______________

Applicable clean-up standards:
- ❑ Non-detect level
- ❑ Background level
- ❑ Risk based clean-up level
- ❑ Federal or state remediation standard

Primary reasons this technology (or combination) was selected:
- ❑ NAVFAC guidance
- ❑ Cost
- ❑ Schedule
- ❑ Regulatory requirements
- ❑ Effectiveness
- ❑ Minimal exposure hazard
- ❑ Other: ______________

Source(s) of funding:	
❑ Base realignment and closure (BRAC) ❑ Installation Restoration Program (IRP)	❑ Defense Environmental Restoration Account (DERA) ❑ Other: ____________

The Contract:

Type of remediation implementation contract:
- ❑ Firm fixed-price (lump sum)
- ❑ Cost reimbursable (cost plus)
- ❑ Unit price
- ❑ Other: ____________

Estimated total contract cost amount (investigation, implementation, monitoring):

____

Implementation contract project duration (months): ____________

Design and construction were done by:
- ❑ Separate contracts
- ❑ In-house design and separate construction contract
- ❑ Design-build contract

What percentage of the implementation project has been completed to date:
- ❑ 0-25%
- ❑ 26-50%
- ❑ 51-75%
- ❑ 76-100 %
- ❑ Project complete

Results to Date:

Project scope change during project:
- ❑ Increased (5% or more)
- ❑ No change
- ❑ Reduced (5% or more)

Project cost:
- ❑ Under budget (2% or more)
- ❑ On buaget
- ❑ Over budget (2% or more)

Anticipated or actual annual operations and maintenance (O&M) cost: ____________

Percentage of total project cost spent on site characterization and study: ____________

Schedule performance:
- ❑ Ahead of schedule (2% or more)
- ❑ On schedule
- ❑ Behind schedule (2% or more)

Project met (or is meeting) regulatory remediation goals:
- ❑ Yes
- ❑ No

Impact on project outcome (1-Positive, 2-No major impact, 3-Negative, 4-N/A):

	1	2	3	4
Project planning	❑	❑	❑	❑
Sampling plan/methods	❑	❑	❑	❑
Laboratory analysis	❑	❑	❑	❑
Implementation contract type	❑	❑	❑	❑
Contract incentives	❑	❑	❑	❑
Contract penalties	❑	❑	❑	❑
Team building/partnering	❑	❑	❑	❑
Contractor performance	❑	❑	❑	❑
Contract disputes	❑	❑	❑	❑
Discovered more contamination	❑	❑	❑	❑
Unanticipated soil, geological, or groundwater conditions	❑	❑	❑	❑
Technology performance	❑	❑	❑	❑
Severe weather (*force majeure*)	❑	❑	❑	❑
Funding	❑	❑	❑	❑
Political involvement	❑	❑	❑	❑
Other: ____________				

Evaluation of overall project results to date:
- ❑ Successful
- ❑ Acceptable
- ❑ Unsuccessful

Would you like a disk copy of the Microsoft Access for Windows database? ❑ Yes ❑ No

Other comments on the project (or any of the questions above):

Please recommend another person who could contribute to this research by filling out project information surveys:

Name: E-mail: Tel:

Fax:

Address:

Appendix C

Data Tables

Project ID	Project Name	Respondent ID	Base	City	State
5	Small Arms Firing Range	1	Bergstrom AFB	Austin	TX
6	Oil Water Separator Removal	1	Bergstrom AFB	Austin	TX
7	Air Injection/Soil Vapor Extraction	8	Bergstrom AFB	Austin	TX
8	Landfills 3-7	1	Bergstrom AFB	Austin	TX
9	Facility 4537, JP8 PST Removal	1	Bergstrom AFB	Austin	TX
10	Base Boundary Pump and Treat	4	Norton AFB	Sacramento	CA
11	Site 1 Removal Action	4	Norton AFB	Sacramento	CA
12	TCE Soil Vapor Extraction	4	Norton AFB		CA
13	Excavate Landfill 5	5	Pease AFB		NH
14	Hydrant System Removal	5	Pease AFB		NH
15	Hydrant System Site Characterization	5	Pease AFB		NH
16	Site 8 Remedial Action	5	Pease AFB		NH
17	Spill Site 10	5	Plattsburgh AFB		NY
18	Boundary Area Hydraulic Containment Sys	6	Lowry AFB	Denver	CO
19	Reactive Wall	6	Lowry AFB	Denver	CO
20	Source Area TCE Plume	6	Lowry AFB	Denver	CO
21	Bioventing at Sites STO 7 and STO 9	6	Lowry AFB	Denver	CO
22	Landfill Cap (OU 2)	6	Lowry AFB	Denver	CO
23	Fire Training Area #2	7	Chanute AFB	Rantoul	IL
24	Building 700 groundwater	7	Chanute AFB	Rantoul	IL
25	Low Level Radioactive Waste Removal	8	Bergstrom AFB	Austin	TX
26	Area 1 TCE Plume	9	Bergstrom AFB	Austin	TX
27	SWMU 9 Fire Department Training Area	9	Bergstrom AFB	Austin	TX
28	SWMU 121/205 Firing Ranges	9	Bergstrom AFB	Austin	TX
29	Site 29, SVE for Vadose Zone	10	Mather AFB		CA
30	Landfills 2-6	10	Mather AFB		CA
31	Site 32, UST	10	Mather AFB		CA
32	Unnamed Stream	11	Carswell AFB	Ft. Worth	TX
33	SVE at IRP sites 1, 2, 3	12	AFP 44	Tucson	AZ

Table C-1 Project Name and Location

Project ID	Project Name	Respondent ID	Base	City	State
34	Hazardous Waste Storage Area Closure	13	Griffiss AFB	Rome	NY
35	Remove USTs	13	Griffiss AFB	Rome	NY
36	Site 1	14	Vandenburg AFB		CA
37	Auto Hobby Shop Soils	6	Lowry AFB	Denver	CO
38	Site 29, SVE/Bioventing	15	Mather AFB		CA
39	990/996	16	Homestead AFB	Homestead	FL
40	McAllister Point Landfill	20	NETC	Newport	RI
41	NAS-1 Wellhead Treatment System	21	NAS Agana	Guam	Marianas Islands
42	TPH Soil Remediation	22	Midway Island		
43	RAC II Delivery Order 7	23	NAS Kingsville	Kingsville	TX
44	D.O. 1 SOW 5	24	NAS	Corpus Christi	TX
45	D.O. 16 SOW 24	24	NAS	Corpus Christi	TX
46	Area "A" Landfill Cap	25	NSB	New London	CT
47	NAWC Trenton	26	Ewing TWP	TWP	NJ
48	Site 2 Fire Training Area	27	NWIRP	Calverton	NY
49	Sutes 3 & 6	28	MCB	Camp Pendleton	CA
50	Site 45 Dry Cleaning Facility	29	MCRD	Parris Island	SC
51	Removal Action at DRMO Manana Storage A	30	FISC	Pearl Harbor	HI
52	PCB Transformer Filter Area Bldg 3009	31	Apra Harbor	Guam	Marianas Islands
53	Dialdrin Removal	32	FISC	Pearl Harbor	HI
54	PCB Removal	32	FISC	Pearl Harbor	HI
55	Sandblast Grit Stabilization	33	Hunters Point SYD	San Francisco	CA
56	Site 1 Northern Riverside Disposal	34	Allegany Ballistics Lab	Rocket Center	WV
57	Mercury Burial Vault Removal	35	PNSYD	Portsmouth	ME
58	Interim Corrective Measures DRMO Facility	35	PNSYD	Portsmouth	ME
59	Industrial Waste Treatment Plant Closure, Bld	35	PNSYD	Portsmouth	ME
60	Removal of USTs	36	Midway	Midway	US
61	RCRA Landfill	37	NAS Mare Island	Vallejo	CA
62	Site 11 Bldg 866	38	NAS Mare Island	Vallejo	CA

Table C-1 Project Name and Location (Continued)

Project ID	Project Name	Respondent ID	Base	City	State
63	Tank Farm #5	20	NETC	Newport	RI
64	Tanks 53/56 Removal Action	20	NETC	Newport	RI
65	UST Removal @CNSYD	39	CNSYD	Charleston	SC
66	UST Removals	40	NAS	Glenview	IL
67	Horizontal Recovery Well Pump and Treat	41	NSCS	Athens	GA
68	Joint Small Arms Range	42	FT Polk	FT Polk	LA
69	PSC 18 Golf Course Rubble Area	43	MCLB	Albany	GA
70	PSC 16 PCB Transformer Pad	43	MCLB	Albany	GA
71	PSC (Carpenter Shop Wood Preservation Ta	43	MCLB	Albany	GA
72	Site Cleanup at Former Gas Station (Site 717	44	NTC	Orlando	FL
73	Soil Remediation at NEX Gas Station	44	Naval Air Station	Meridian	MS
74	Biometric Pumping	44	NAS Whiting Field	Milton	FL
75	Site 1 Landfill	45	NAS	Pensacola	FL
76	Biocomposting of Explosive Contaminated So	48	NSWC	Crane	IN
77	NAS Cecil Field	47	NAS Cecil Field	Jacksonville	FL
78	MCB Hawaii Biopile	48	MCB Kaneohe	Kaneohe Bay	HI
79	Sandblast Grit	49	Hunters Point	Hunters Point	CA
80	Base Catalyzed Decomposition Process	50	Naval Station	Guam	Marianas Islands
81	Sumps	51	Longhorn Army Ammunition	Karnack	TX
82	Site 16 Landfill	51	Longhorn Army Ammunition	Karnack	TX
83	Site 12 Landfill	51	Longhorn Army Ammunition	Karnack	TX
84	Burning Ground #3	51	Longhorn Army Ammunition	Karnack	TX
85	Free Product Removal System	52	NAS North Island	Coronado	CA
86	TCE Plume Remediation	53	Naval Air Station	Fort Worth	TX
87	32nd Street NEX Service Station	54	Naval Station	San Diego	CA
88	OU # 1 Site 16	55	MCAS	Cherry Point	NC
89	OU #2 Site 10	55	MCAS	Cherry Point	NC

Table C-1 Project Name and Location (Continued)

Project ID	Fuel Hydrocarbons	Chlorinated Solvents	Metals	PCBs	Other	Explanation	Comments
5	0	0	1	0	0		To reduce 10,000 CY of soil to non-hazardous material
6	0	1	1	0	0		
7	1	0	1	0	0		At conclusion of remediation contract, no further action required, so there is no O&M cost.
8	0	0	0	0	1	Uncharacterized landfills	
9	1	0	0	0	0		
10	0	1	0	0	0		Treatment system is operational and is controlling plume. O&M to continue until levels of TCE are below 5 ppb.
11	0	1	1	0	0		
12	0	1	0	0	0		
13	1	1	1	0	1	Pesticides	Landfill wastes must be excavated to eliminate contact with groundwater and capped.
14	1	0	0	0	0		Scope: remove 52 - 50,000 gal underground storage tanks (USTs) and 10 - 2,000 gal USTs and contaminated soil. Remove all distributed piping not paved over.
15	0	0	0	0	0		Site characterization with goal of natural attenuation. Former hydrant system within 100 feet of public water well.
16	1	1	1	1	0		Need to contain plume and remediate site quickly as it is located in a National Register of Historic Places site Newington Town Forest. Pump and treatd for containment only. 75% of the surface was capped.
17	1	1	0	0	0		Originally scoped as SVE. Changed to excavation because of supposed high water table. Project is much more expensive initially. No O&M costs following excavation.
18	0	1	0	0	0		

Table C-2 Project Contaminant and Comments

Project ID	Fuel Hydrocarbons	Chlorinated Solvents	Metals	PCBs	Other	Explanation	Comments
19	0	1	0	0	0		
20	0	1	0	0	0		
21	1	0	0	0	0		
22	0	1	0	0	1	Methane gas/landfill waste	
23	1	0	1	1	0		
24	1	0	0	0	0		
25	0	0	0	0	1	Low level radioactive waste	
26	0	1	0	0	0		
27	1	1	0	0	0		
28	0	0	1	0	0		
29	0	1	0	0	0		Contract cost amount does not include investigation.
30	0	0	0	0	1	Refuse	Very successful project, a model for other bases. Contract cost amount does not include investigation.
31	1	0	0	0	0		Depth of contamination was greater than excavation capability. Contract cost does not include investigation. Significantly more contamination discovered than planned.
32	1	0	1	0	0		
33	0	1	0	0	0		SVE system works fine, but resin vapor system (RVS) innovative technology has caused several problems. RVS is being used to treat the extracted vapors, instead of activated carbon beds, but it doesn't work properly.
34	0	0	0	1	0		
35	1	0	0	0	0		
36	1	0	0	0	0		
37	1	0	0	0	0		

Table C-2 Project Contaminant and Comments (Continued)

Project ID	Fuel Hydrocarbons	Chlorinated Solvents	Metals	PCBs	Other	Explanation	Comments
38	1	0	0	0	0		
39	1	0	0	0	0		
40	1	1	1	1	0		
41	0	1	0	0	0		Operation on the treatment system will not be continuous if the contaminant is treated on a consistent level below the MCL.
42	1	0	0	0	0		
43	1	0	0	0	0		
44	1	1	1	0	1	lead	
45	1	0	0	0	0		
46	1	0	1	1	0		
47	0	1	0	0	0		
48	1	1	1	1	1	PAH's	This is a pilot study.
49	0	0	0	0	1	Pesticides	
50	0	1	0	0	0		
51	0	0	1	0	0		
52	0	0	0	1	0		
53	0	0	0	0	1	Pesticide Dialdrin	
54	0	0	0	1	0		
55	0	0	1	0	0		This project is a new technology demonstration. Material recycled in asphalt mix.
56	0	1	1	0	1	Explosives	Free Product (NAPL) is suspected in the ground water.
57	0	0	1	0	0		
58	1	1	1	1	0		

Table C-2 Project Contaminant and Comments (Continued)

Project ID	Fuel Hydrocarbons	Chlorinated Solvents	Metals	PCBs	Other	Explanation	Comments
59	0	0	0	0	1	Residual Chemicals from Industrial Waste	
60	1	0	0	0	0		
61	1	1	1	1	1	Asbestos	
62	0	0	0	1	0		Demonstration Project on Innovative Technology
63	1	0	0	0	0		
64	1	1	0	0	0		
65	1	0	0	0	0		Contract Type is SPORTENVDETCHASN (Base closure)
66	1	0	0	0	0		
67	1	0	0	0	0		
68	0	0	1	0	0		Army & Navy Joint Project
69	0	0	0	1	0		
70	0	0	0	1	0		Institutional Controls & Long Term Monitoring
71	0	1	0	0	1	Pesticides	
72	1	0	0	0	0		
73	1	0	0	0	0		
74	1	0	0	0	0		
75	1	1	1	0	0		
76	0	0	0	0	1	INT, RDX, HMX (explosives)	
77	1	1	0	0	0		9 months for soil and 15 years for Ground Water (GW)
78	1	0	0	0	0		Technology Demonstration. Project didn't meet goals in the reg. Permit, but only soils from on base were used allowing less stringent environmental regulation considerations.
79	0	0	1	0	0		
80	0	0	0	1	0		

Table C-2 Project Contaminant and Comments (Continued)

Project ID	Fuel Hydrocarbons	Chlorinated Solvents	Metals	PCBs	Other	Explanation	Comments
81	0	1	1	0	0		
82	0	1	1	0	0		
83	0	1	1	0	0		
84	0	1	0	0	0		
85	1	0	0	0	0		
86	1	1	1	0	0		
87	1	0	0	0	1	MTBE	
88	0	1	0	0	0		Team building/partnering was the most effective part of the work in reducing cost and saving time.
89	1	1	0	0	0		Select monitored natural attenuation with hot spot remediation of soil on a 40 acre landfill with residual soil and GW contamination saved about $4M in construction and over $10M in O&M costs

Table C-2 Project Contaminant and Comments (Continued)

	Reason for Technology Selection							Applicable Cleanup Standards			
Project ID	Military Guidance	Cost	Schedule	Regulatory Requirements	Effectiveness	Minimize Exposure Hazard	Other	Non-detect	Background	Risk based	Fed or State
5	0	0	1	1	0	0	1	0	1	0	0
6	0	1	1	0	1	0	0	0	1	0	0
7	0	1	1	0	1	0	0	0	1	1	0
8	0	0	0	1	1	1	0	0	0	1	1
9	0	1	0	0	0	0	0	0	1	0	0
10	0	1	0	1	0	0	1	0	0	0	1
11	0	1	0	1	1	0	0	0	0	1	0
12	0	1	0	1	0	0	1	0	0	0	1
13	0	1	0	1	1	0	1	0	0	0	1
14	1	1	0	1	1	0	0	1	0	0	1
15	1	1	1	1	1	1	1	0	0	0	1
16	1	0	0	0	1	0	1	0	0	0	1
17	0	0	0	0	1	0	0	0	0	0	1
18	0	1	0	1	1	0	0	0	0	0	1
19	0	0	0	0	0	0	1	0	0	0	1
20	0	0	0	1	1	0	0	0	0	0	1
21	1	1	0	0	1	0	0	0	0	0	1
22	0	0	0	0	0	0	1	0	0	1	0
23	0	0	1	1	0	0	1	0	0	1	0
24	0	0	0	0	1	0	0	0	0	0	1
25	0	0	0	0	1	0	0	0	1	0	0
26	0	1	0	0	0	0	0	0	0	1	0

Table C-3 Reason for Technology Selection and Applicable Cleanup Standards

	Reason for Technology Selection							Applicable Cleanup Standards			
Project ID	Military Guidance	Cost	Schedule	Regulatory Requirements	Effectiveness	Minimize Exposure Hazard	Other	Non-detect	Background	Risk based	Fed or State
27	0	1	0	0	1	0	0	0	0	1	0
28	0	1	0	1	0	0	0	0	0	1	0
29	0	1	0	1	1	0	0	0	0	0	1
30	0	1	0	1	0	0	0	0	0	0	1
31	0	1	0	1	1	0	0	0	0	0	1
32	0	1	1	0	1	0	0	0	0	1	0
33	1	0	0	0	1	0	0	0	0	0	1
34	0	0	0	1	0	0	0	0	0	0	1
35	1	0	0	0	0	0	0	1	0	0	0
36	0	1	0	0	1	0	0	0	0	0	1
37	1	1	1	1	1	0	0	0	0	1	1
38	1	1	0	1	0	0	0	0	0	1	1
39	0	0	1	0	1	0	0	0	0	0	1
40	0	0	0	1	1	1	0	0	0	1	0
41	0	1	1	0	1	0	0	0	0	0	1
42	0	1	1	0	1	1	1	0	0	1	0
43	0	1	0	0	0	0	0	0	0	0	1
44	1	1	0	1	0	0	0	0	0	1	1
45	1	1	0	1	0	0	0	0	0	0	1
46	0	1	0	1	1	0	0	0	0	1	0
47	0	0	0	0	1	0	0	0	0	0	1
48	0	0	0	0	1	0	0	0	0	0	1

Table C-3 Reason for Technology Selection and Applicable Cleanup Standards (Continued)

	Reason for Technology Selection							Applicable Cleanup Standards			
Project ID	Military Guidance	Cost	Schedule	Regulatory Requirements	Effectiveness	Minimize Exposure Hazard	Other	Non-detect	Background	Risk based	Fed or State
49	0	1	0	0	1	0	0	0	0	1	0
50	1	0	0	0	0	0	0	0	1	0	0
51	0	0	1	1	0	0	0	0	0	1	0
52	0	1	0	0	0	0	0	0	0	0	1
53	0	0	1	0	1	0	0	0	0	1	0
54	0	0	1	1	1	0	0	0	0	0	1
55	1	0	0	0	1	0	1	0	0	0	1
56	0	0	0	1	1	0	0	0	0	0	1
57	0	0	0	1	1	0	0	0	0	0	1
0	0	0	0	1	1	0	0	0	0	0	1
59	0	0	0	1	1	0	0	0	0	0	1
61	0	0	0	0	0	0	1	0	0	0	1
62	0	0	0	0	0	0	1	0	0	0	1
63	1	0	0	1	0	0	0	0	0	0	1
64	1	1	0	1	1	0	0	0	0	0	1
65	0	1	1	0	1	0	0	0	0	1	0
66	0	0	1	0	0	0	0	0	0	1	0
67	0	0	0	0	0	0	1	0	0	0	1
69	0	0	0	1	0	1	0	0	1	0	0
70	0	0	0	0	0	1	1	0	0	0	1
71	0	1	0	0	0	1	0	1	0	0	0
72	0	0	0	0	1	0	0	0	0	1	0

Table C-3 Reason for Technology Selection and Applicable Cleanup Standards (Continued)

	Reason for Technology Selection							Applicable Cleanup Standards			
Project ID	Military Guidance	Cost	Schedule	Regulatory Requirements	Effectiveness	Minimize Exposure Hazard	Other	Non-detect	Background	Risk based	Fed or State
73	1	0	0	0	0	0	0	0	0	1	0
74	0	0	0	0	0	0	1	0	0	1	0
75	0	0	0	1	0	0	0	0	0	0	1
76	0	1	0	1	0	0	0	0	0	1	0
77	0	1	1	0	1	0	0	0	0	0	1
78	0	0	0	0	0	0	1	0	0	0	1
79	0	1	0	0	0	0	0	0	0	0	1
80	1	0	0	0	0	0	1	0	0	1	1
81	0	0	0	1	1	1	0	0	0	1	0
82	0	0	0	1	1	1	0	0	0	1	0
83	0	0	0	1	1	1	0	0	0	1	0
84	0	0	0	1	1	1	0	0	0	1	0
85	0	0	0	1	1	0	0	0	0	0	1
86	0	0	0	1	1	0	0	0	1	0	1
87	0	1	0	0	1	0	0	0	1	1	0
88	0	1	0	1	1	0	0	0	0	1	1
89	0	1	0	1	0	0	0	0	0	1	0

Table C-3 Reason for Technology Selection and Applicable Cleanup Standards (Continued)

Project ID	Regulatory Goals	Project Planning	Sampling Plan	Lab Analysis	Implementation Contract	Contract Incentives	Contract Penalties	Team Building	Contractor Performance	Contract Disputes	Additional Contamination	Site Conditions	Technology Performance	Severe Weather	Funding	Political Involvement	Project Assessment
5	1	1	2	2	1	1	2	4	1	4	4	2	1	4	4	1	Acceptable
6	1	1	1	1	2	2	2	1	1	4	3	4	1	2	2	2	Successful
7	1	1	1	1	2	1	1	3	1	3	3	2	1	2	2	2	Acceptable
8	1	1	1	1	4	1	1	1	1	4	2	4	1	3	3	3	Successful
9	1	1	1	1	2	2	2	1	1	4	3	3	1	4	4	3	Acceptable
10	1	1	2	2	2	2	2	2	1	2	2	3	1	2	2	2	Successful
11	1	1	1	1	2	2	2	2	1	2	3	3	2	2	2	2	Acceptable
12	1	1	3	2	2	2	2	2	1	2	2	2	1	2	2	2	Successful
13	1	1	2	2	1	4	4	2	1	4	2	1	4	4	1	4	Successful
14	1	1	1	1	1	4	4	1	1	4	2	4	4	4	1	4	Successful
15	1	1	1	1	1	4	4	1	1	4	2	4	4	4	1	4	Successful
16	0	1	2	2	1	4	4	1	1	4	2	4	1	4	1	1	Successful
17	1	3	3	2	2	4	4	3	3	4	3	3	4	4	4	4	Acceptable
18	1	1	1	2	2	2	2	1	2	2	2	2	2	2	2	2	Successful
19	1	1	1	1	1	1	1	1	1	2	2	2	1	2	1	2	Successful
20	1	1	1	1	2	2	2	1	2	2	2	2	2	2	2	2	Successful
21	1	1	1	2	2	2	2	1	2	2	2	2	2	2	1	2	Acceptable
22	1	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	Acceptable
23	1	1	1	1	1	1	4	1	1	4	1	4	1	4	1	4	Successful
24	1	1	1	1	1	1	4	1	1	4	2	4	1	4	1	4	Successful
25	1	2	1	1	1	4	4	2	1	4	4	1	1	4	1	2	Successful
26	0	1	1	1	1	2	2	1	1	2	2	2	1	2	2	3	Successful
27	0	1	1	2	2	2	2	1	1	2	4	2	4	4	4	2	Successful
28	1	1	2	2	2	2	2	1	1	2	2	2	1	2	2	2	Successful
29	0	1	1	1	1	2	4	1	1	4	2	4	1	4	4	4	Successful
30	1	1	2	2	1	2	4	1	1	4	2	4	1	4	4	4	Successful

Table C-4 Project Results

Project ID	Regulatory Goals	Project Planning	Sampling Plan	Lab Analysis	Implementation Contract	Contract Incentives	Contract Penalties	Team Building	Contractor Performance	Contract Disputes	Additional Contamination	Site Conditions	Technology Performance	Severe Weather	Funding	Political Involvement	Project Assessment
31	1	3	2	2	4	4	4	4	1	4	3	3	4	3	4	4	Acceptable
32	1	1	1	1	1	4	4	1	1	4	4	2	1	2	1	2	Successful
33	0	1	2	1	1	4	4	1	1	4		2	3	2	1	4	Acceptable
34	1	1	2	2	1	2	2	1	1	2	1	2	2	2	2	4	Acceptable
35	1	1	2	2	1	1	1	1	1	2	1	2	2	2	2	4	Successful
36	1		1	1	1	4	4	1	1	4	2	2	1	4	1	4	Successful
37	1	2	1	2	1	1	2	1	2	2	1	2	1	2	1	2	Acceptable
38	1	1	2	1	1	2	4	4	1	4	1	22	1	4	1	4	Successful
39	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	Successful
40	1	1	2	2	1	2	1	1	1	4	2	2	1	3	1	2	Successful
41	1	1	1	1	1	2	2	2	1	2	4	4	1	3	1	1	Acceptable
42	1	2	2	2	2	2	2	1	3	3	4	4	3	2	2		Successful
43	1	1	1	1	1	1	4	4	1	4	4	4	1	4	1	4	Successful
44	1	2	2	1	2	2	4	2	1	4	2	2	1	2	2	4	Acceptable
45	1	2	2	2	3	2	4	1	2	4	2	2	3	2	3	4	Acceptable
46	1	2	1	2	1	1	2	1	1	2	4	4	2	4	2	2	Successful
47	1	1	1	1	1	2	2	1	1	1	2	2	1	2	2	2	Successful
48	1	2	2	2	1	2	4	2	1	4	4	4	1	3	2	4	Successful
49	1	3	3	2	1	1	2	1	1	2	3	3	1	3	2	2	Successful
50	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	Acceptable
51	1	1	1	1	1	1	4	1	1	4	2	2	2	2	2	1	Successful
52	1	1	1	1	1	4	4	4	1	3	3	3	1	3	3	1	Successful
53	1	1	2	2	1	4	4	4	1	4	2	4	1	4	2	3	Successful
54	1	3	1	1	3	2	2	4	2	4	3	2	1	4	3	3	Successful
55	1	1	1	1	2	4	4	4	2	4	4	4	1	4	4	4	Successful
56	1	1	1	1	1	1	1	1	1	4	4	4	1	4	1	3	Successful

Table C-4 Project Results (Continued)

Project ID	Regulatory Goals	Project Planning	Sampling Plan	Lab Analysis	Implementation Contract	Contract Incentives	Contract Penalties	Team Building	Contractor Performance	Contract Disputes	Additional Contamination	Site Conditions	Technology Performance	Severe Weather	Funding	Political Involvement	Project Assessment
57	1	1	1	1	1	1	2	2	1	2	2	2	1	2	2	2	Successful
58	1	1	2	2	2	2	2	2	1	2	3	2	2	2	2	2	Acceptable
59	1	1	2	2	1	1	2	2	1	2	2	2	1	2	2	2	Successful
60	1	1	1	1	1	4	4	2	1	4	4	4	1	4	1	4	Successful
63	1	2	2	2	3	4	2	4	3	2	4	3	3	2	1	4	Acceptable
64	1	1	1	1	2	4	4	4	2	4	4	2	1	4	1	4	Successful
65	1	1	1	1	3	4	4	2	1	3	2	2	2	2	2	3	Acceptable
66	1	1	1	1	1	1	4	1		2			2	3	2	1	Successful
67	0	1	1	1	1	1	4	4	2	2	2	3	1	4	2	2	Acceptable
68	1	1	1	1	2	4	4	1	3	4	4	4	1	4	1	3	Successful
69	1	2	2	2	2	1	4	4	1	4	4	4	1	4	2	3	Successful
70	1	2	2	2	3	4	4	4	3	3	4	4	2	4	4	3	Acceptable
71	1	1	3	3	1	4	4	4	1	4	3	4	1	4	4	2	Successful
72	1	1	1	1	1	4	4	1	2	4	3	2	1	3	4	3	Acceptable
73	0	1	1	1	1	4	4	1	2	4	3	3	3	4	2	2	Unsuccessful
74	1	1	2	2	1	4	4	1	1	4	4	2	1	2	2	2	Successful
75	1	1	1	1	2	2	4	1	1	4	4	4	1	4	4	4	Successful
76	1	3	2	2	1	1	4	3	3	4	4	4	3	4	1	4	Acceptable
77	1	2	1	2	1	2	2	1	2	2	4	4		3	2	2	Successful
78	0	2	1	2	2	2	2	1	1	4	4	4	1	1	2	2	Successful
79	1	1	1	1	1	2	2	4	1	4	2	4	1	1	3	3	Successful
80	1	3	1	1	2	4	4	4	2	4	3	3	1	3	2	3	Successful
81	1	1	1	1	1	1	1	1	1	4	4	4	1	4	1	1	Successful
82	1	1	1	1	1	1	1	1	1	4	4	4	1	4	1	1	Successful
83	1	1	1	1	1	1	1	1	1	4	4	4	1	4	1	1	Successful

Table C-4 Project Results (Continued)

Project ID	Regulatory Goals	Project Planning	Sampling Plan	Lab Analysis	Implementation Contract	Contract Incentives	Contract Penalties	Team Building	Contractor Performance	Contract Disputes	Additional Contamination	Site Conditions	Technology Performance	Severe Weather	Funding	Political Involvement	Project Assessment
84	1	1	1	1	1	1	1	1	1	4	4	4	1	4	1	1	Successful
85	1	1	1	1	2	2	2	1	2	2	3	3	1	2	1	2	Successful
86	0	2	2	2	2	2	2	1	2	2	1	1	2	2	1	2	Unsuccessful
87	1	1	1	1	2	2	2	1	3	2	2	1	1	3	2	3	Successful
88	0	1	2	2	1	1	1	1	1	4	4	2	1	2			Successful
89	1	1	2	2	1	2	2	1	1	4	4	4	1	4	2	2	Successful

Table C-4 Project Results (Continued)

Project ID	Contract Type	Total Cost	Duration	Management Structure	Percent Complete	O&M Cost
5	Cost reimbursable (cost plus)	0	7		Project complete	0
6	Cost reimbursable (cost plus)	0	3		Project complete	0
7	Cost reimbursable (cost plus)	4518700	18	Design-build contract	Project complete	0
8	Cost reimbursable (cost plus)	0	36	Design-build contract	76-99%	0
9	Cost reimbursable (cost plus)	0	12		76-99%	0
10	Firm, fixed price (lump sum)	7000000	18	Design-build contract	76-99%	1000000
11	Firm, fixed price (lump sum)	3000000	20	Design-build contract	76-99%	0
12		0	0	Design-build contract	76-99%	0
13	Cost reimbursable (cost plus)	6680000	19	Separate contracts	Project complete	150000
14	Cost reimbursable (cost plus)	6910000	24		Project complete	0
15	Time and materials	3100000	18		Project complete	0
16	Cost reimbursable (cost plus)	10200000	18	Design-build contract	Project complete	815500
17	Cost reimbursable (cost plus)	2360000	9	Design-build contract	76-99%	0
18	Cost reimbursable (cost plus)	800000	24	Separate contracts	26-50%	260000
19	Firm, fixed price (lump sum)	500000	8	Design-build contract	76-99%	0
20	Cost reimbursable (cost plus)	2000000	36	Separate contracts	26-50%	260000
21	Cost reimbursable (cost plus)	350000	30	Separate contracts	76-99%	100000
22		15000000	20	Separate contracts	0-25%	500000
23	Cost reimbursable (cost plus)	250000	6	In-house design & construction	76-99%	0
24	Cost reimbursable (cost plus)	274000	18	In-house design & construction	76-99%	0
25	Firm, fixed price (lump sum)	175500	3	Design-build contract	Project complete	0
26	Cost reimbursable (cost plus)	0		Separate contracts	76-99%	1500000
27	Cost reimbursable (cost plus)	1500000	3	Separate contracts	0-25%	0
28	Cost reimbursable (cost plus)	800000	5	Separate contracts	51-75%	0
29	Cost reimbursable (cost plus)	938900	72	Design-build contract	51-75%	240000
30	Cost reimbursable (cost plus)	10200000	30	Design-build contract	Project complete	276000

Table C-5 Contract Type and Cost

Project ID	Contract Type	Total Cost	Duration	Management Structure	Percent Complete	O&M Cost
31	Cost reimbursable (cost plus)	431400	18	Design-build contract	Project complete	0
32	Cost reimbursable (cost plus)	517000	0	Separate contracts	51-75%	0
33	Cost reimbursable (cost plus)	6300000	8	Design-build contract	76-99%	0
34	Cost reimbursable (cost plus)	3500000	24		0-25%	0
35	Cost reimbursable (cost plus)	2500000	10		51-75%	0
36	Time and Materials	450000	24		76-99%	25000
37	Cost reimbursable (cost plus)	400000	16	Separate contracts	76-99%	0
38	Cost reimbursable (cost plus)	1000000	0	Separate contracts	51-75%	240000
39	Cost reimbursable (cost plus)	800000	7	Design-build contract	76-99%	200000
40	Cost reimbursable (cost plus)	18000000	36	Separate contracts	76-99%	300000
41	Cost reimbursable (cost plus)	900000	60	In-house design & construction	51-75%	10000
42	Firm, fixed price (lump sum)	400000	2	Separate contracts	Project complete	0
43	Cost reimbursable (cost plus)	2700000	6	Design-build contract	76-99%	700000
44	Cost reimbursable (cost plus)	7900000	18	Separate contracts	Project complete	0
45	Cost reimbursable (cost plus)	900000	16	Design-build contract	76-99%	0
46	Cost reimbursable (cost plus)	8000000	10	Separate contracts	51-75%	30000
47	Cost reimbursable (cost plus)	28000000	360	Separate contracts	76-99%	400000
48	Cost reimbursable (cost plus)	410000	22	Design-build contract	Project complete	0
49	Cost reimbursable (cost plus)	9100000	18	Design-build contract	Project complete	0
50	Cost reimbursable (cost plus)	1000000	24	Separate contracts	0-25%	5000
51	Cost reimbursable (cost plus)	1500000	6	Separate contracts	Project complete	0
52	Cost reimbursable (cost plus)	5000000	60	In-house design & construction	76-99%	0
53	Cost reimbursable (cost plus)	651626	4	Separate contracts	Project complete	0
54	Firm, fixed price (lump sum)	1757008	4	In-house design & construction	Project complete	0
55	Cost reimbursable (cost plus)	446000	60	Design-build contract	Project complete	0
56	Cost reimbursable (cost plus)	7000000	360	Separate contracts	26-50%	4000000

Table C-5 Contract Type and Cost (Continued)

Project ID	Contract Type	Total Cost	Duration	Management Structure	Percent Complete	O&M Cost
57	Cost reimbursable (cost plus)	45000	1	In-house design & construction	Project complete	0
58	Firm, fixed price (lump sum)	250000	3	Separate contracts	Project complete	0
59	Cost reimbursable (cost plus)	200000	3	Separate contracts	Project complete	0
60	Cost reimbursable (cost plus)	2000000	24	Design-build contract	Project complete	2000000
61	Cost reimbursable (cost plus)		0	Separate contracts	0-25%	0
63	Cost reimbursable (cost plus)	0	24	Separate contracts	Project complete	100000
64	Firm, fixed price (lump sum)	2750000	24	Separate contracts	Project complete	500000
65	Unit price	2700000	48	In-house design & construction	0-25%	0
66	Cost reimbursable (cost plus)	0	36	Design-build contract	Project complete	0
67	Cost reimbursable (cost plus)	2500000	36	Separate contracts	76-99%	75000
68	Cost reimbursable (cost plus)	3000000	27	Separate contracts	Project complete	0
69	Cost reimbursable (cost plus)	60000	3	Separate contracts	Project complete	0
70	Cost reimbursable (cost plus)	1000000	24	Separate contracts	Project complete	10000
71	Firm, fixed price (lump sum)	90000	6	Separate contracts	76-99%	0
72	Cost reimbursable (cost plus)	900000	120	Separate contracts	Project complete	0
73	Cost reimbursable (cost plus)	700000	36	Separate contracts	76-99%	80000
74	Cost reimbursable (cost plus)	500000	12	Separate contracts	76-99%	60000
75	Cost reimbursable (cost plus)	9300000	24	Separate contracts	0-25%	210000
76	Cost reimbursable (cost plus)	26500000	90	Separate contracts	0-25%	0
77	Cost reimbursable (cost plus)	1932000	9	Separate contracts	76-99%	10000
78	Cost reimbursable (cost plus)	150000	16	In-house design & construction	Project complete	0
79	Unit price	700000	24	Design-build contract	Project complete	0
80	Cost reimbursable (cost plus)	17000000	60	Separate contracts	Project complete	3600000
81	Cost reimbursable (cost plus)	5000000	12	Design-build contract	Project complete	0
82	Firm, fixed price (lump sum)	0	18	Design-build contract	51-75%	200000
83	Firm, fixed price (lump sum)	5000000	18	Design-build contract	76-99%	0

Table C-5 Contract Type and Cost (Continued)

Project ID	Contract Type	Total Cost	Duration	Management Structure	Percent Complete	O&M Cost
84	Cost reimbursable (cost plus)	24000000	360	Design-build contract	51-75%	250000
85	Cost reimbursable (cost plus)	4000000	36	Design-build contract	Project complete	300000
86	Cost reimbursable (cost plus)	0	0	Separate contracts	0-25%	0
87	Cost reimbursable (cost plus)	750000	36	Separate contracts	51-75%	50000
88	Cost reimbursable (cost plus)	2150000	24	Separate contracts	26-50%	225000
89	Cost reimbursable (cost plus)	1750000	4	Separate contracts	26-50%	215000

Table C-5 Contract Type and Cost (Continued)

Project ID	BRAC	IRP	DERA	Other	Cost Performance	%Spent On Study	Schedule Performance	Scope Change
5	1	0	0	0	Over budget (2% or more)	37	Ahead of schedule (2% or more)	No change
6	1	0	0	0	On budget	0	On schedule	No change
7	1	1	0	0	On budget	0	Behind schedule (2% or more)	No change
8	1	1	0	0	Over budget (2% or more)	0	Behind schedule (2% or more)	Increased (5% or more)
9	1	0	0	0	Over budget (2% or more)	0	On schedule	Increased (5% or more)
10	1	0	0	0		0	On schedule	Increased (5% or more)
11	1	0	0	0	On budget	25	On schedule	Increased (5% or more)
12	1	0	0	0	On budget	0	On schedule	Increased (5% or more)
13	1	0	0	0	Under budget (2% or more)	0	Ahead of schedule (2% or more)	No change
14	1	0	0	0	On budget	0	On schedule	No change
15	1	0	0	0	On budget	100	On schedule	No change
16	1	0	0	0	On budget	20	On schedule	No change
17	1	0	0	0	Over budget (2% or more)	5	Behind schedule (2% or more)	Increased (5% or more)
18	1	0	0	0	On budget	25	On schedule	No change
19	1	1	0	0	On budget	20	On schedule	No change
20	1	0	0	0	On budget	28	On schedule	No change
21	1	0	0	0	Over budget (2% or more)	25	On schedule	No change
22	1	0	0	0	Over budget (2% or more)	2	Behind schedule (2% or more)	Increased (5% or more)
23	1	0	0	0	Under budget (2% or more)	0	Ahead of schedule (2% or more)	Reduces (5% or more)
24	1	0	0	0	Under budget (2% or more)	0	Ahead of schedule (2% or more)	No change
25	1	1	0	0	Under budget (2% or more)	19	Behind schedule (2% or more)	No change
26	1	0	0	0	On budget	0	On schedule	Increased (5% or more)
27	1	0	0	0	On budget	20	On schedule	No change
28	1	0	0	0	On budget	50	On schedule	No change
29	1	0	0	0	On budget	0	On schedule	No change

Table C-6 Contract Funding and Performance

Project ID	BRAC	IRP	DERA	Other	Cost Performance	%Spent On Study	Schedule Performance	Scope Change
30	1	0	0	0	Under budget (2% or more)	0	Ahead of schedule (2% or more)	Increased (5% or more)
31	1	0	0	0	Over budget (2% or more)	0	Behind schedule (2% or more)	Increased (5% or more)
32	1	0	0	0	Under budget (2% or more)	68	On schedule	Reduces (5% or more)
33	0	0	1	0	On budget	0	On schedule	Increased (5% or more)
34	1	0	0	0	On budget	20	On schedule	Increased (5% or more)
35	1	0	0	0	Under budget (2% or more)	10	On schedule	Reduces (5% or more)
36	0	0	1	0	On budget	55	Ahead of schedule (2% or more)	Increased (5% or more)
37	1	0	0	0	Over budget (2% or more)	25	Behind schedule (2% or more)	Increased (5% or more)
38	1	0	0	0	On budget	30	On schedule	No change
39	1	0	0	0	On budget	0	On schedule	No change
40	0	0	1	0	Over budget (2% or more)	20	On schedule	Increased (5% or more)
41	1	0	0	0	Over budget (2% or more)	25	On schedule	Increased (5% or more)
42	1	0	0	0	On budget	50	On schedule	No change
44	1	0	0	0	Over budget (2% or more)	0	On schedule	Increased (5% or more)
45	0	1	0	0	Over budget (2% or more)	0	Behind schedule (2% or more)	Increased (5% or more)
46	0	0	1	0	Under budget (2% or more)	15	Ahead of schedule (2% or more)	No change
47	1	0	0	0	On budget	60	On schedule	No change
48	0	1	1	0	On budget	100	On schedule	Increased (5% or more)
49	0	0	1	0	On budget	5	On schedule	Increased (5% or more)
50	0	0	1	0	Over budget (2% or more)	60	Behind schedule (2% or more)	Increased (5% or more)
51	0	1	0	0	Under budget (2% or more)	80	On schedule	Reduces (5% or more)
52	0	0	1	0	Over budget (2% or more)	0	Behind schedule (2% or more)	Increased (5% or more)
53	0	1	0	0	Over budget (2% or more)	4	On schedule	Increased (5% or more)
54	0	1	0	0	Over budget (2% or more)	10	On schedule	Increased (5% or more)
55	0	0	1	0	Over budget (2% or more)	5	Behind schedule (2% or more)	Increased (5% or more)

Table C-6 Contract Funding and Performance (Continued)

Project ID	BRAC	IRP	DERA	Other	Cost Performance	%Spent On Study	Schedule Performance	Scope Change
56	0	0	0	1	Under budget (2% or more)	0	On schedule	Reduces (5% or more)
57	0	0	1	0	On budget	10	On schedule	No change
59	0	0	1	0	Under budget (2% or more)	20	On schedule	No change
60	1	0	0	0	On budget	4	On schedule	No change
63	0	0	1	0	Over budget (2% or more)	65	On schedule	No change
64	0	0	1	0	Over budget (2% or more)	20	On schedule	Increased (5% or more)
65	1	0	0	0	Over budget (2% or more)	30	Behind schedule (2% or more)	No change
66	1	0	0	0	Over budget (2% or more)	0	On schedule	Increased (5% or more)
67	0	0	1	0	On budget	15	On schedule	Increased (5% or more)
68	0	0	0	0	On budget	45	Behind schedule (2% or more)	No change
69	0	1	0	0	On budget	10	On schedule	No change
70	0	1	0	0	On budget	60	On schedule	No change
71	0	1	0	0	Over budget (2% or more)	10	On schedule	Increased (5% or more)
72	1	0	0	0	Under budget (2% or more)	60	On schedule	Increased (5% or more)
73	0	0	1	0	Over budget (2% or more)	60	Behind schedule (2% or more)	Increased (5% or more)
74	0	0	1	0	Under budget (2% or more)	40	On schedule	No change
75	0	1	1	0	On budget	8	Behind schedule (2% or more)	No change
76	0	1	0	0	Over budget (2% or more)	12	Behind schedule (2% or more)	Increased (5% or more)
77	1	0	0	0	On budget	10	Ahead of schedule (2% or more)	Increased (5% or more)
78	0	1	0	0	Over budget (2% or more)	0	Behind schedule (2% or more)	Increased (5% or more)
79	1	0	0	0	On budget	30	Behind schedule (2% or more)	Increased (5% or more)
80	0	0	1	0	Over budget (2% or more)	0	Behind schedule (2% or more)	Increased (5% or more)
81	0	0	1	0	On budget	25	On schedule	No change
82	0	0	1	0	On budget	50	On schedule	No change
83	0	0	1	0	On budget	30	On schedule	No change

Table C-6 Contract Funding and Performance (Continued)

Project ID	BRAC	IRP	DERA	Other	Cost Performance	%Spent On Study	Schedule Performance	Scope Change
84	0	0	1	0	On budget	30	On schedule	No change
85	0	0	1	0	On budget	2	On schedule	No change
86	1	1	1	0	Over budget (2% or more)	40	Behind schedule (2% or more)	Increased (5% or more)
87	0	0	0	1	On budget	5	Behind schedule (2% or more)	No change
88	0	1	0	0	Under budget (2% or more)	25	Behind schedule (2% or more)	Reduces (5% or more)
89	0	0	0	1	Under budget (2% or more)	80	On schedule	Reduces (5% or more)

Table C-6 Contract Funding and Performance (Continued)

Project ID	Contamination Depth	Extent Of Plume	Water Table Depth	Site Reuse
5	21-30 feet		11-20 feet	In 1-3 years
6	11-20 feet		21-30 feet	In 1-3 years
7	21-30 feet	is completely on site	11-20 feet	In 1-3 years
8	11-20 feet		21-30 feet	In 1-3 years
9	21-30 feet		21-30 feet	In 1-3 years
10	Over 50 feet	extends beyond the property line	Over 50 feet	In 1-3 years
11	31-40 feet			In 1-3 years
12	Over 50 feet	extends beyond the property line	Over 50 feet	In 1-3 years
13	11-20 feet	is completely on site	0-10 feet	No definite plans (or no information)
14	11-20 feet	is completely on site	0-10 feet	In 1-3 years
15	21-30 feet	is completely on site	0-10 feet	In 1-3 years
16	21-30 feet	extends beyond the property line	0-10 feet	No definite plans (or no information)
17	0-10 feet	is completely on site	0-10 feet	No definite plans (or no information)
18	21-30 feet	extends beyond the property line	11-20 feet	In 1-3 years
19	21-30 feet	extends beyond the property line	11-20 feet	In 1-3 years
20	31-40 feet	extends beyond the property line	11-20 feet	In 1-3 years
21	11-20 feet	is completely on site	11-20 feet	In 1-3 years
22	11-20 feet		11-20 feet	In 1-3 years
23	11-20 feet	is completely on site	0-10 feet	In 4-10 years
24	11-20 feet	is completely on site	0-10 feet	In 1-3 years
25	21-30 feet		21-30 feet	No definite plans (or no information)
26	Over 50 feet	extends beyond the property line	Over 50 feet	In 1-3 years
27	11-20 feet	is completely on site	21-30 feet	In 1-3 years
28	0-10 feet		21-30 feet	No definite plans (or no information)
29	Over 50 feet			In 1-3 years
30	Over 50 feet			No definite plans (or no information)
31	21-30 feet			In 4-10 years
32	0-10 feet		11-20 feet	In 1-3 years
33	Over 50 feet	extends beyond the property line	Over 50 feet	No definite plans (or no information)
34	0-10 feet		0-10 feet	No definite plans (or no information)

Table C-7 Extent of Contamination

Project ID	Contamination Depth	Extent Of Plume	Water Table Depth	Site Reuse
35	0-10 feet		11-20 feet	No definite plans (or no information)
36	11-20 feet	is completely on site	11-20 feet	No definite plans (or no information)
37	0-10 feet		11-20 feet	In 1-3 years
38	Over 50 feet		Over 50 feet	In 1-3 years
39	0-10 feet	is completely on site	0-10 feet	In 1-3 years
40	31-40 feet	extends beyond the property line	11-20 feet	No definite plans (or no information)
41	Over 50 feet	has an unknown extent	Over 50 feet	In 4-10 years
42	0-10 feet	is completely on site	11-20 feet	In 1-3 years
43	11-20 feet		11-20 feet	In 1-3 years
44	Over 50 feet	is completely on site	11-20 feet	No definite plans (or no information)
45	0-10 feet	is completely on site	0-10 feet	No definite plans (or no information)
46	21-30 feet	is completely on site	0-10 feet	In 1-3 years
47	Over 50 feet	has an unknown extent	0-10 feet	In 1-3 years
48	Over 50 feet	is completely on site	21-30 feet	In 4-10 years
49	0-10 feet		0-10 feet	No definite plans (or no information)
50	21-30 feet	is completely on site	0-10 feet	No definite plans (or no information)
51	0-10 feet		Over 50 feet	In 1-3 years
52	11-20 feet		0-10 feet	No definite plans (or no information)
53	0-10 feet		21-30 feet	In 1-3 years
54	0-10 feet		0-10 feet	In 1-3 years
55	0-10 feet		0-10 feet	In 4-10 years
56	Over 50 feet	is completely on site	0-10 feet	No definite plans (or no information)
57	11-20 feet		11-20 feet	In 4-10 years
58	11-20 feet	extends beyond the property line	11-20 feet	In 4-10 years
59	0-10 feet		11-20 feet	No definite plans (or no information)
60	21-30 feet	is completely on site	0-10 feet	In 1-3 years
61	21-30 feet	is completely on site	21-30 feet	No definite plans (or no information)
62	0-10 feet		11-20 feet	
63	31-40 feet	is completely on site	11-20 feet	No definite plans (or no information)
64	31-40 feet	extends beyond the property line	11-20 feet	No definite plans (or no information)

Table C-7 Extent of Contamination (Continued)

Project ID	Contamination Depth	Extent Of Plume	Water Table Depth	Site Reuse
65	0-10 feet	is completely on site	0-10 feet	In 1-3 years
66	11-20 feet		Over 50 feet	In 1-3 years
67	21-30 feet	extends beyond the property line	11-20 feet	No definite plans (or no information)
68	0-10 feet			No definite plans (or no information)
69	0-10 feet		21-30 feet	In 1-3 years
70	31-40 feet		41-50 feet	No definite plans (or no information)
71	11-20 feet		21-30 feet	No definite plans (or no information)
72	11-20 feet	extends beyond the property line	11-20 feet	In 4-10 years
73	0-10 feet	is completely on site	0-10 feet	In 1-3 years
74	Over 50 feet		Over 50 feet	No definite plans (or no information)
75	31-40 feet		0-10 feet	
76	0-10 feet		11-20 feet	No definite plans (or no information)
77	31-40 feet	is completely on site	0-10 feet	In 4-10 years
78	0-10 feet		0-10 feet	No definite plans (or no information)
79	0-10 feet			In 4-10 years
80	11-20 feet		11-20 feet	In 1-3 years
81	0-10 feet	is completely on site	21-30 feet	No definite plans (or no information)
82	21-30 feet	is completely on site	0-10 feet	No definite plans (or no information)
83	21-30 feet		41-50 feet	No definite plans (or no information)
84	11-20 feet	is completely on site	11-20 feet	No definite plans (or no information)
85	11-20 feet	is completely on site	11-20 feet	In 1-3 years
86	21-30 feet	is completely on site	11-20 feet	In 1-3 years
87	11-20 feet	extends beyond the property line	0-10 feet	No definite plans (or no information)
88	Over 50 feet	is completely on site	11-20 feet	No definite plans (or no information)
89	11-20 feet	is completely on site	11-20 feet	No definite plans (or no information)

Table C-7 Extent of Contamination (Continued)

Project ID	Regulatory Goals	Soil Vapor Extraction	Air Sparging	Biodegradation	Bioventing	Redox	Composting	Land Disposal	Incineration	Soil Cap	Treatment Wall	Pump and Treat	Other	Explanation
5	1	0	0	0	0	0	0	1	0	0	0	0	0	
6	1	0	0	0	0	0	0	1	0	0	0	0	0	
7	1	1	1	0	0	0	0	0	0	0	0	0	0	
8	1	0	0	0	0	0	0	0	0	1	0	0	0	
9	1	0	0	0	0	0	0	1	0	0	0	0	1	Tanks recycled
10	1	0	0	0	0	0	0	0	0	0	0	1	0	
11	1	0	0	0	0	0	0	1	0	0	0	0	0	
12	1	1	0	0	0	0	0	0	0	0	0	0	0	
13	1	0	0	0	0	0	0	1	0	1	0	0	0	
14	1	0	0	0	0	0	0	1	0	0	0	0	0	
15	1	0	0	0	0	0	0	0	0	0	0	0	1	Site characterization
16	0	1	0	1	0	0	0	0	0	1	0	1	0	
17	1	0	0	0	0	0	0	1	1	0	0	0	0	
18	1	0	0	0	0	0	0	0	0	0	0	1	0	
19	1	0	0	0	0	0	0	0	0	0	1	0	0	
20	1	0	0	0	0	0	0	0	0	0	0	0	1	Dual Phase Extraction
21	1	0	0	0	1	0	0	0	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	1	0	0	0	
23	1	0	0	0	0	0	0	1	0	0	0	0	1	Pipe removal
24	1	0	0	0	0	0	0	0	0	0	0	1	0	
25	1	0	0	0	0	0	0	1	0	0	0	0	0	
26	0	0	0	1	0	0	0	0	0	0	0	0	0	
27	0	0	0	0	0	0	0	1	0	0	0	0	0	
28	1	0	0	0	0	0	0	0	0	0	0	0	1	Gravity Separation/Soil Washing
29	0	1	0	0	1	0	0	0	0	0	0	0	0	
30	1	0	0	0	0	0	0	1	0	1	0	0	0	

Table C-8 Regulatory Goals and Remediation Technology

Project ID	Regulatory Goals	Soil Vapor Extraction	Air Sparging	Biodegradation	Bioventing	Redox	Composting	Land Disposal	Incineration	Soil Cap	Treatment Wall	Pump and Treat	Other	Explanation
31	1	0	0	0	0	0	1	0	0	0	0	0	1	Excavated prior to composting
32	1	0	0	0	0	0	0	1	0	0	0	0	0	
33	0	1	0	0	0	0	0	0	0	0	0	0	1	Resin adsorption vapor treatment
34	1	0	0	0	0	0	0	1	0	0	0	0	0	
35	1	0	0	0	0	0	0	1	0	0	0	0	0	
36	1	0	0	1	0	0	0	0	0	0	0	0	0	
37	1	0	0	0	0	0	0	1	0	0	0	0	0	
38	1	1	0	0	1	0	0	0	0	0	0	0	0	
39	1	0	0	0	0	0	0	1	0	0	0	0	0	
40	1	0	0	0	0	0	0	0	0	1	0	0	1	Armor stone revetment
41	1	0	0	0	0	0	0	0	0	0	0	1	0	
42	1	0	0	0	0	0	0	0	0	0	0	0	1	Recycle for paving
43	1	0	0	1	0	0	0	0	0	0	0	0	0	
44	1	0	0	0	0	0	1	1	0	0	0	0	0	
45	1	0	0	0	0	0	0	0	0	0	0	0	1	Product Recover & Vapor Treatment or Bio-Slurp
46	1	0	0	0	0	0	0	0	0	1	0	0	0	
47	1	0	0	0	0	0	0	0	0	0	0	1	0	
48	1	1	1	0	0	0	0	0	0	0	0	0	0	
49	1	0	0	0	0	0	0	0	0	0	0	0	1	Excavation, fixation & recycled as landfill cap
50	1	0	0	0	0	0	0	0	0	0	0	0	1	In-well Stripping
51	1	0	0	0	0	0	0	1	0	0	0	0	0	
52	1	0	0	0	0	0	0	0	0	0	0	0	1	Base Catalyzed Decomposition Process
53	1	0	0	0	0	0	0	1	0	0	0	0	0	

Table C-8 Regulatory Goals and Remediation Technology (Continued)

Project ID	Regulatory Goals	Soil Vapor Extraction	Air Sparging	Biodegradation	Bioventing	Redox	Composting	Land Disposal	Incineration	Soil Cap	Treatment Wall	Pump and Treat	Other	Explanation
54	1	0	0	0	0	0	0	1	0	0	0	0	0	
55	1	0	0	0	0	0	0	0	0	0	0	0	1	Recycled to make asphalt
56	1	0	0	0	0	0	0	0	0	0	0	1	0	
57	1	0	0	0	0	0	0	1	0	0	0	0	0	
59	1	0	0	0	0	0	0	0	0	0	0	0	1	Triple Rinsing of Process Tanks and Hand Cleaning
60	1	1	1	0	0	0	0	1	0	0	0	0	0	
61	0	0	0	0	0	0	0	0	0	1	0	0	0	RCRA Subtitle "C" Cap
62	0	0	0	0	0	0	0	0	0	0	0	0	1	In Situ Thermal Desorption
63	1	0	0	1	0	0	0	0	0	0	0	0	1	Monitoring
64	1	0	0	0	0	1	0	0	0	0	0	1	0	
65	1	0	0	0	0	0	1	0	0	0	0	0	0	
66	1	0	0	0	0	0	0	1	0	0	0	0	0	
67	0	1	0	0	0	0	0	0	0	0	0	1	0	
68	1	0	0	0	0	0	0	0	0	0	0	0	1	Physical Separation / Chemical Leaching
69	1	0	0	0	0	0	0	1	0	0	0	0	0	
70	1	0	0	0	0	0	0	1	0	0	0	0	1	Low Permeability Subsurface Membrane Liner
71	1	0	0	0	0	0	0	1	0	0	0	0	0	
72	1	0	0	0	0	0	0	0	1	0	0	0	0	
73	0	1	0	0	0	0	0	0	0	0	0	1	0	
74	1	0	1	0	1	0	0	0	0	0	0	0	0	
75	1	0	0	0	0	0	0	0	0	0	0	0	1	Monitoring w/GW extraction / inteception
76	1	0	0	0	0	0	1	0	0	0	0	0	0	

Table C-8 Regulatory Goals and Remediation Technology (Continued)

Project ID	Regulatory Goals	Soil Vapor Extraction	Air Sparging	Biodegradation	Bioventing	Redox	Composting	Land Disposal	Incineration	Soil Cap	Treatment Wall	Pump and Treat	Other	Explanation
77	1	0	0	0	0	0	0	1	0	0	0	0	1	Natural Attenuation for GW
78	0	0	0	0	0	0	0	0	0	0	0	0	1	Biopile (exsitu)
79	1	0	0	0	0	0	0	0	0	0	0	0	1	Recycle Grit as raw material for ashpalt
80	1	0	0	0	0	0	0	0	0	0	0	0	1	Base Catalyzed Decompostion Process
81	1	0	0	0	0	0	0	1	0	0	0	0	0	
82	1	0	0	1	0	0	0	0	0	1	0	1	0	
83	1	0	0	0	0	0	0	0	0	1	0	0	0	
84	1	0	0	0	0	0	0	1	0	0	0	1	0	
85	1	0	0	0	0	0	0	0	0	0	0	0	1	Free-Product Pumping & Removal
86	0	1	0	0	1	0	0	0	0	0	0	1	0	
87	1	1	0	0	0	0	0	0	0	0	0	0	0	
88	0	1	1	0	0	0	0	0	0	0	0	0	0	
89	1	1	0	0	0	0	0	0	0	0	0	0	1	Monitored Natural Attenuation for GW

Table C-8 Regulatory Goals and Remediation Technology (Continued)

	Geology Classification				Contamination has affected			Groundwater affected	
Project ID	Tight clay/silt (impermeable soils)	Loose sand/gravel (permeable soils)	Relatively impermeable bedrock	Permeable bedrock	Soil	Groundwater	Air	Dissolved in groundwater	Free product (NAPL)
5	1	0	0	0	1	0	0		
6	0	1	0	0	1	0	0		
7	0	1	0	0	1	1	0	1	1
8	1	0	0	0	1	0	0		
9	0	1	0	0	1	0	0		
10	1	1	0	0	0	1	0	1	0
11	0	1	0	0	1	0	0		
12	1	1	0	0	1	1	0	1	0
13	1	1	0	1	1	1	0	1	0
14	0	1	0	0	1	1	0	1	1
15	0	1	0	0	1	1	0	1	1
16	1	1	0	1	1	1	0	1	1
17	0	1	0	0	1	1	0	1	0
18	1	0	0	0	1	1	0	1	1
19	1	0	0	0	0	1	0	0	1
20	1	0	0	0	0	1	0	0	1
21	1	0	0	0	1	1	0	0	1
22	1	0	0	0	1	0	0	0	1
23	1	1	0	0	1	1	0	0	1
24	1	0	0	0	1	1	0	1	0
25	1	0	0	0	1	0	0		
26	0	1	0	0	0	1	0	1	0

Table C-9 Site Geology

	Geology Classification				Contamination has affected			Groundwater affected	
Project ID	Tight clay/silt (impermeable soils)	Loose sand/gravel (permeable soils)	Relatively impermeable bedrock	Permeable bedrock	Soil	Groundwater	Air	Dissolved in groundwater	Free product (NAPL)
27	1	0	0	0	1	1	0	1	0
28	1	0	0	0	1	0	0		
29	0	1	0	0	1	0	0		
30	0	1	0	0	1	0	0		
31	0	1	0	0	1	0	0		
32	0	1	0	0	1	0	0		
33	1	0	0	0	1	1	0	1	0
34	0	1	0	0	1	0	0		
35	0	1	0	0	1	0	0		
36	0	1	0	0	1	1	0	1	0
37	1	0	0	0	1	0	0		
38	0	1	0	0	1	0	0		
39	0	0	0	1	1	1	0	1	1
40	0	0	0	1	1	1	0	1	1
41	0	0	0	1	0	1	0	1	0
42	0	1	0	0	1	1	0	0	1
43	1	0	0	0	1	0	0		
44	1	0	0	0	1	1	0	0	1
45	0	1	0	0	1	1	0	0	1
46	0	1	0	0	1	1	0	1	0
47	0	0	0	1	1	1	0	1	1
48	0	1	0	0	1	1	0	1	1

Table C-9 Site Geology (Continued)

	Geology Classification				Contamination has affected			Groundwater affected	
Project ID	Tight clay/silt (impermeable soils)	Loose sand/gravel (permeable soils)	Relatively impermeable bedrock	Permeable bedrock	Soil	Groundwater	Air	Dissolved in groundwater	Free product (NAPL)
49	0	1	0	0	1	0	0		
50	0	1	0	0	1	1	0	1	0
51	1	0	0	0	1	0	0		
52	0	1	0	0	1	0	0		
53	1	0	0	0	1	0	0		
54	1	0	0	0	1	0	0		
55	0	1	0	0	1	0	1		
56	1	0	0	0	1	1	0	1	1
57	0	1	1	0	1	0	0		
58	0	1	1	0	1	1	0	1	0
59	0	1	1	0	1	0	0		
60	0	1	0	0	1	1	0	1	1
61	1	0	0	0	1	1	0	1	0
62	1	0	0	0	1	0	0		
63	1	1	1	1	1	1	0	1	1
64	1	1	1	1	1	1	0	1	1
65	1	0	0	0	1	1	0	1	0
66	1	0	0	0	1	0	0		
67	1	0	0	1	1	1	0	1	0
68	1	0	0	0	1	0	0		
69	1	0	0	0	1	0	0		
70	1	0	0	0	1	0	0		

Table C-9 Site Geology (Continued)

	Geology Classification				Contamination has affected			Groundwater affected	
Project ID	Tight clay/silt (impermeable soils)	Loose sand/gravel (permeable soils)	Relatively impermeable bedrock	Permeable bedrock	Soil	Groundwater	Air	Dissolved in groundwater	Free product (NAPL)
71	1	0	0	0	1	0	0		
72	0	1	0	0	1	1	0	1	1
73	1	0	0	0	1	1	0	1	1
74	0	1	0	0	1	0	0		
75	0	1	0	0	0	1	0	1	0
76	0	1	0	0	1	0	0		
77	0	1	0	0	1	1	0	1	0
78	0	1	0	0	1	0	0		
79	0	1	0	0	1	0	0		
80	0	1	0	0	1	0	0		
81	1	0	0	0	1	0	0		
82	1	0	0	0	1	1	0	1	0
83	1	0	0	0	1	0	0		
84	1	0	0	0	1	1	0	1	0
85	0	1	0	0	1	1	0	1	1
86	1	1	1	0	1	1	0	1	1
87	1	1	0	0	1	1	0	1	1
88	0	1	0	0	1	1	0	1	0
89	0	1	0	0	1	1		1	0

Table C-9 Site Geology (Continued)

Appendix D

Chi-Square Contingency Tables

Table D-1 Chi-Square Contingency Table for Cost vs. Contaminant

Table D-2 Chi-Square Contingency Table for Schedule vs. Contaminant

Table D-3 Chi-Square Contingency Table for Cost vs. Technology

Table D-4 Chi-Square Contingency Table for Schedule vs. Technology

Table D-5 Chi-Square Contingency Table for Scope Change vs. Technology

Table D-6 Chi-Square Contingency Table for Cost vs. Reason for Technology Selection

Table D-7 Chi-Square Contingency Table for Schedule vs. Reason for Technology Selection

Table D-8 Chi-Square Contingency Table for Scope Change vs. Reason for Technology Selection

Cost vs Contaminant

Observed Frequency

	Chlorinated Solvents	Fuel Hydrocarbons	Metals	Other Contaminants	PCBs	Row Total
Over Budget	26.47	36.59	20.83	42.86	36.36	163.11
On /Under Budget	73.53	63.41	79.17	57.14	63.64	336.89
Column Total	100.00	100.00	100.00	100.00	100.00	500.00

Expected Frequency

	Chlorinated Solvents	Fuel Hydrocarbons	Metals	Other Contaminants	PCBs	Row Total
Over Budget	32.62	32.62	32.62	32.62	32.62	163.11
On /Under Budget	67.38	67.38	67.38	67.38	67.38	336.89
Column Total	100.00	100.00	100.00	100.00	100.00	500.00

Chi-Square Terms

	Chlorinated Solvents	Fuel Hydrocarbons	Metals	Other Contaminants	PCBs
Over Budget	1.1600	0.4815	4.2601	3.2113	0.4292
On /Under Budget	0.5616	0.2331	2.0626	1.5548	0.2078

Chi-Square:	14.16
Alpha:	0.0010
Critical Value:	18.4662
Decision:	Accept Ho

Table D-1 Chi-Square Contingency Table for Cost vs Contaminant

Schedule vs Contaminant

Observed Frequency

	Chlorinated Solvents	Fuel Hydrocarbons	Metals	Other Contaminants	PCBs	Row Total
Behind Schedule	17.65	26.83	25.00	35.71	18.18	123.37
On / Ahead of Schedule	82.35	73.17	75.00	64.29	81.82	376.63
Column Total	100.00	100.00	100.00	100.00	100.00	500.00

Expected Frequency

	Chlorinated Solvents	Fuel Hydrocarbons	Metals	Other Contaminants	PCBs	Row Total
Behind Schedule	24.67	24.67	24.67	24.67	24.67	123.37
On / Ahead of Schedule	75.33	75.33	75.33	75.33	75.33	376.63
Column Total	100.00	100.00	100.00	100.00	100.00	500.00

Chi-Square Terms

	Chlorinated Solvents	Fuel Hydrocarbons	Metals	Other Contaminants	PCBs
Behind Schedule	2.0014	0.1882	0.0043	4.9394	1.7084
On / Ahead of Schedule	0.6556	0.0616	0.0014	1.6180	0.5596

Chi-Square:	11.74	11.74
Alpha:	0.01	0.0194
Critical Value:	13.2767	11.7392
Decision:	Accept Ho	Accept Ho

Table D-2 Chi-Square Contingency Table for Schedule vs Contaminant

Cost vs Technology									
Observed Frequency	Air Sparging	Biodegradation	Composting	Land Disposal	Other Technologies	Pump and Treat	Soil Cap	Soil Vapor Extraction	Row Total
Over Budget	0	20	100	20	30.8	30.8	33.3	16.7	251.60
On / Under Budget	100	80	0	80	69.2	69.2	66.7	83.3	548.40
Column Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	800.00
Expected Frequency	Air Sparging	Biodegradation	Composting	Land Disposal	Other Technologies	Pump and Treat	Soil Cap	Soil Vapor Extraction	Row Total
Over Budget	31.45	31.45	31.45	31.45	31.45	31.45	31.45	31.45	251.60
On / Under Budget	68.55	68.55	68.55	68.55	68.55	68.55	68.55	68.55	548.40
Column Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	800.00
Chi-Square Terms	Air Sparging	Biodegradation	Composting	Land Disposal	Other Technologies	Pump and Treat	Soil Cap	Soil Vapor Extraction	
Over Budget	31.4500	4.1686	149.4150	4.1686	0.0134	0.0134	0.1088	6.9177	
On / Under Budget	14.4289	1.9125	68.5500	1.9125	0.0062	0.0062	0.0499	3.1738	
Chi-Square:	286.2956		286.2956						
Alpha:	0.01		0.0010						
Critical Value:	18.4753		24.3213						
Decision:	Reject Ho		Reject Ho						

Table D-3 Chi-Square Contingency Table for Cost vs Technology

Schedule vs Technology

Observed Frequency

	Air Sparging	Biodegradation	Composting	Land Disposal	Other Technologies	Pump and Treat	Soil Cap	Soil Vapor Extraction	Row Total
Behind Schedule	50.00	0	75	10	23.1	15.4	16.7	41.7	231.90
Ahead / On Schedule	50.00	100	25	90	76.9	84.6	83.3	58.3	568.10
Column Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	800.00

Expected Frequency

	Air Sparging	Biodegradation	Composting	Land Disposal	Other Technologies	Pump and Treat	Soil Cap	Soil Vapor Extraction	Row Total
Behind Schedule	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	231.90
Ahead / On Schedule	71.01	71.01	71.01	71.01	71.01	71.01	71.01	71.01	568.10
Column Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	800.00

Chi-Square Terms

	Air Sparging	Biodegradation	Composting	Land Disposal	Other Technologies	Pump and Treat	Soil Cap	Soil Vapor Extraction
Behind Schedule	15.2316	28.9875	73.0367	12.4373	1.1958	6.3690	5.2085	5.5751
Ahead / On Schedule	6.2176	11.8328	29.8138	5.0769	0.4881	2.5998	2.1261	2.2758

Chi-Square:	208.47	208.47
Alpha:	0.01	0.0160
Critical Value:	18.4753	17.2253
Decision:	Reject Ho	Reject Ho

Table D-4 Chi-Square Contingency Table for Schedule vs Technology

Scope Change vs Technology

Observed Frequency

	Air Sparging	Biodegradation	Composting	Land Disposal	Other Technologies	Pump and Treat	Soil Cap	Soil Vapor Extraction	Row Total
Increased Scope	25	40	75	30	38.5	46.2	33.3	50	338.00
Decreased / Unchanged S	75	60	25	70	61.5	53.8	66.7	50	462.00
Column Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	800.00

Expected Frequency

	Air Sparging	Biodegradation	Composting	Land Disposal	Other Technologies	Pump and Treat	Soil Cap	Soil Vapor Extraction	Row Total
Increased Scope	42.25	42.25	42.25	42.25	42.25	42.25	42.25	42.25	338.00
Decreased / Unchanged S	57.75	57.75	57.75	57.75	57.75	57.75	57.75	57.75	462.00
Column Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	800.00

Chi-Square Terms

	Air Sparging	Biodegradation	Composting	Land Disposal	Other Technologies	Pump and Treat	Soil Cap	Soil Vapor Extraction
Increased Scope	7.0429	0.1198	25.3861	3.5518	0.3328	0.3693	1.8959	1.4216
Decreased / Unchanged S	5.1526	0.0877	18.5725	2.5985	0.2435	0.2702	1.3871	1.0400

Chi-Square:	69.47	69.47
Alpha:	0.01	0.0010
Critical Value:	18.4753	24.3213
Decision:	Reject Ho	Reject Ho

Table D-5 Chi-Square Contingency Table for Scope Change vs Technology

Cost vs Reason for Technology Selection

Observed Frequency

	Schedule	Cost	Regulatory Requirements	Minimal Exposure Hazard	Effectiveness	AFCEE Guidance	Row Total
Over Budget	41.2	32.4	30.8	27.5	27.1	25	184.00
On or Under Budget	58.8	67.6	69.2	72.5	72.9	75	416.00
Column Total	100.00	100.00	100.00	100.00	100.00	100.00	600.00

Expected Frequency

	Schedule	Cost	Regulatory Requirements	Minimal Exposure Hazard	Effectiveness	AFCEE Guidance	Row Total
Over Budget	30.67	30.67	30.67	30.67	30.67	30.67	184.00
On or Under Budget	69.33	69.33	69.33	69.33	69.33	69.33	416.00
Column Total	100.00	100.00	100.00	100.00	100.00	100.00	600.00

Chi-Square Terms

	Schedule	Cost	Regulatory Requirements	Minimal Exposure Hazard	Effectiveness	AFCEE Guidance
Over Budget	3.6180	0.0980	0.0006	0.3270	0.4148	1.0471
On or Under Budget	1.6003	0.0433	0.0003	0.1446	0.1835	0.4631

Chi-Square:	7.94	7.94
Alpha:	0.01	0.1000
Critical Value:	15.0863	9.2363
Decision:	Accept Ho	Accept Ho

Table D-6 Chi-Square Contingency Table for Cost vs Reason for Technology

Schedule vs Reason for Technology Selection

Observed Frequency	Schedule	Cost	Regulatory Requirements	Minimal Exposure Hazard	Effectiveness	AFCEE Guidance	Row Total
Behind Schedule	17.7	26.3	20	9.1	22.9	12.5	108.50
On Schedule	82.3	73.7	80	90.9	77.1	87.5	491.50
Column Total	100.00	100.00	100.00	100.00	100.00	100.00	600.00

Expected Frequency	Schedule	Cost	Regulatory Requirements	Minimal Exposure Hazard	Effectiveness	AFCEE Guidance	Row Total
Behind Schedule	18.08	18.08	18.08	18.08	18.08	18.08	108.50
On Schedule	81.92	81.92	81.92	81.92	81.92	81.92	491.50
Column Total	100.00	100.00	100.00	100.00	100.00	100.00	600.00

Chi-Square Terms	Schedule	Cost	Regulatory Requirements	Minimal Exposure Hazard	Effectiveness	AFCEE Guidance
Behind Schedule	0.0081	3.7335	0.2031	4.4627	1.2830	1.7239
On Schedule	0.0018	0.8242	0.0448	0.9852	0.2832	0.3806

Chi-Square:	13.93	13.93
Alpha:	0.01	0.0160
Critical Value:	15.0863	13.9392
Decision:	Accept Ho	Accept Ho

Table D-7 Chi-Square Contingency Table for Schedule vs Reason for Technology

Scope Change vs Reason for Technology Selection

Observed Frequency	Schedule	Cost	Regulatory Requirements	Minimal Exposure Hazard	Effectiveness	AFCEE Guidance	Row Total
Increased Scope	17.7	50	37.5	27.3	6.25	25	163.75
Dec / No Change	82.36	50.01	62.50	72.73	93.75	75.00	436.34
Column Total	100.06	100.01	100.00	100.03	100.00	100.00	600.09

Expected Frequency	Schedule	Cost	Regulatory Requirements	Minimal Exposure Hazard	Effectiveness	AFCEE Guidance	Row Total
Increased Scope	27.30	27.29	27.29	27.29	27.29	27.29	163.75
Dec / No Change	72.76	72.72	72.71	72.73	72.71	72.71	436.34
Column Total	100.06	100.01	100.00	100.03	100.00	100.00	600.09

Chi-Square Terms	Schedule	Cost	Regulatory Requirements	Minimal Exposure Hazard	Effectiveness	AFCEE Guidance
Increased Scope	3.3779	18.9011	3.8221	0.0000	16.2190	0.1918
Dec / No Change	1.2677	7.0932	1.4343	0.0000	6.0867	0.0720

Chi-Square:	58.47	58.47
Alpha:	0.01	0.0010
Critical Value:	15.0863	20.5147
Decision:	Reject Ho	Reject Ho

Table D-8 Chi-Square Contingency Table for Scope Change vs Reason for Technology

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VITA

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